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THE DECEMBER SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

DECEMBER, 1934

THE ORIGIN, RISE AND DECLINE OF *HOMO SAPIENS*

By Professor WILLIAM KING GREGORY

COLUMBIA UNIVERSITY AND AMERICAN MUSEUM OF NATURAL HISTORY

HISTORICALLY the origin of man has been heavily beclouded by myths. Man makes himself the center of almost every cosmogony and the gods take sides for or against the tribal hero. This was true even among the Greeks, to say nothing of other primitive Aryans. The anthropocentric world of antiquity is typified by the Babylonian concept of the daily course of the sun, which returned each night to the east after traversing the subterranean land of the dead.

After a few flashes of Greek speculation on the origin of living creatures, Aristotle taught that men and animals have comparable parts and are generated in the same general way, and that man has an animal-like body inhabited by a divine soul. This dualism became orthodox throughout the Christian era and is held by the vast majority of civilized peoples even to-day.

The road to the Darwinian view of man's origin ran partly through the field of anatomy. The fact that pain often appears to be localized doubtless led physicians to study the internal organs, but such simple direct motives were perhaps conditioned and distorted by preconceived theories of the nature of disease. Astrology, always an anthropocentric philosophy, was then as now the enemy of an objective science of anatomy. It was not until many millennia of halting accumulations that, under the powerful solvent supplied by Darwin, the formerly isolated sciences of human anatomy, comparative anatomy, taxonomy, paleontology, geology and astronomy dissolved their own boundaries to form the science of anthropogeny, which deals with the origin of man.

Recently scientists have been going through another cycle of division, specialization and mutual recrimination which has greatly emboldened the enemies of Darwinian science and has enabled even astrology to win back multitudes to its fold. But the reexamination of our foundations which has been constantly going on leaves the science of anthropogeny, I believe, in a much stronger position than it was before, because it is supported by a vast and ever-growing accumulation of objectively established facts. Whatever may be the theories of mathematicians regarding infinitely large or infinitely small spaces and times, paleontologists have to do only with the ascertainable sequence of events in the one-way stream of earth history. These events, in so far as they deal with the origin and rise of the vertebrates, took place during a period of the order of magnitude of five hundred million years.

Man is a sort of living solar engine running by means of the potential en-

FIG. 1. MAN'S DEBT TO THE LOWER VERTEBRATES

SPECIMENS POSED IN PRIMITIVE TETRAPOD POSITION IN ORDER TO SHOW MAN'S INHERITANCE FROM THE LOWER VERTEBRATES OF EVERY BONE IN THE SKELETON.

I. DEVONIAN LOBE-FIN (*Eusthenopteron*).
II. CARBONIFEROUS AMPHIBIAN (*Microbrachium*).
III. PRIMITIVE PERMO-CARBONIFEROUS REPTILE (*Seymouria*).
IV. PROGRESSIVE TRIASSIC PRO-MAMMAL (*Cynognathus*).
V. PRIMITIVE MAMMAL (*Opossum*).
VI. PRIMITIVE LEMUROID EOCENE PRIMATE (*Notharctus*).
VII. TYPICAL ANTHROPOID (*Chimpanzee*).
VIII. MAN.

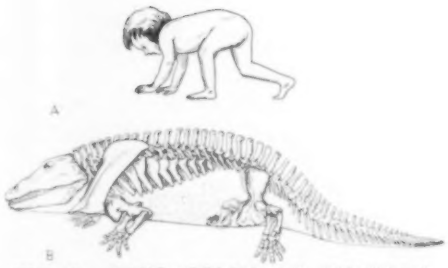


FIG. 2. COMPARISON OF PERMIAN AMPHIBIAN (*ERYOPS*) AND MODERN CHILD, RUNNING ON ALL FOURS

ergy that he has stolen from the plants and animals. This of course is nothing new, but for our present purpose it is fundamental. On the physical side man is primarily a machine for the transformation of potential into kinetic energy and on the biological side man is in a sense a parasite and a robber, sponging on the plants, killing the animals and eating them both. Moreover, as we shall presently see, man's ancestors have practically always been robbers, not until recently killers of big game but persistent harriers of creatures smaller than themselves. So that there is more than a kernel of truth in Bobby Burns's scornful lines:

My ancient but ignoble blood
Hath rolled through scoundrels ever since the Flood.

The first business of a robber after he has secured his booty is to get away with it before some other member of the profession comes up to demand a share. For that reason, among others, vertebrates are provided with a locomotor apparatus, including a backbone and pectoral and pelvic limbs. *Homo sapiens* is found in possession of this accessory to crime. He conceals it by strutting about on his hind legs and looking as dignified as possible, but this small child (Fig. 2), quite in the manner of small children, is giving away family secrets and his actions speak louder than words; for in running on all fours he reverts, so to speak, to the quadrupedal habit.

FIG. 3. THE LOCOMOTOR APPARATUS OF A TYPICAL FISH (*ROCCUS LINEATUS*)

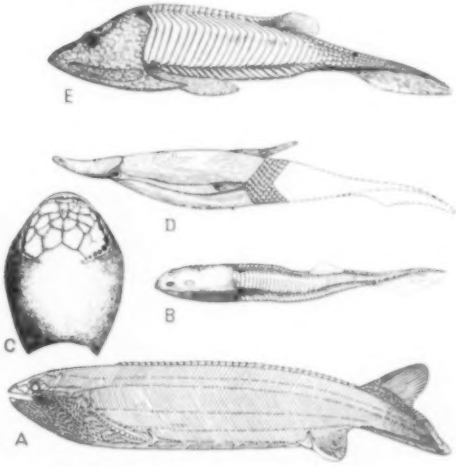


FIG. 4. SOME OF OUR EARLIEST KNOWN KINSFOLK

UPPER SILURIAN AND DEVONIAN OSTRACODERMS. A. *Pterolepis* (AFTER KIAER). B. *Trematapsis* (AFTER ROHON). C. *Trematapsis* (AFTER PATTEN). D. *Pteraspis* (AFTER POWRIE AND LANKESTER). E. *Cephalaspis* (COMPOSITE, MAINLY AFTER PATTEN).

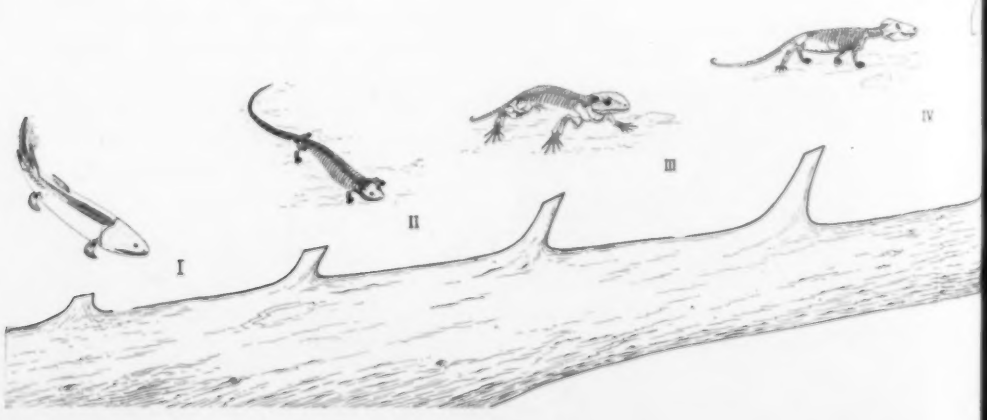
The locomotor system of *Homo sapiens*, like that of other vertebrates, is distressingly complicated in its details, but what may be called its basic and chief subsequent patents are of a masterly directness and simplicity. A fish moves through the water, as we know, by bending its elastic body first to one side, then to the other, so that it waves like a flag. It is enabled to do this because of its serially arranged, contractile myomeres or W-shaped muscle

flakes, which in contracting pull on the septa between them. Each myomere may be said to be the larger locomotor unit of the vertebrate body, and from these simple, serially arranged units the more complex axial and appendicular musculatures of the higher vertebrates have been derived. The smaller units of the locomotor apparatus are the single muscle cells, which have the basic property of contracting when stimulated by their nerve fibrils, thereby performing mechanical work. Exactly how they do this lies beyond my field, but the point is that in contracting the muscle cells use up some of the energy stored in the body and thus contribute to the endless round of getting, storing and spending energy which makes up the game of life.

In Fig. 1 our friend *Homo sapiens* is seen in the daily line-up, divested of his god-like exterior and forced to assume the suppliant posture of his humbler brethren. He is instantly distinguishable from them, however, by his swollen head. The five-and-ten system of prehensile organs, which is one of his most useful possessions, he has inherited from a long line of nefarious ancestors, and no other animal has been more successful in beating Mother Nature at her own game.

The earliest known forms of the vertebrates, namely, the ostracoderms of Silurian and Devonian times, were already in full possession of the basic vertebrate patents and were in these respects nearer to man than they were to their unknown invertebrate ancestors. However, they had not yet attained jaws of the shark type and probably fed on very small animals or organic particles.

From ostracoderm to man the gap is mediated by a procession of fossil and recent forms. Although none of these forms may lie in the direct line of ascent to man, they are the residue after the elimination of thousands of other vertebrates which were specialized in other directions; and all the forms of this residual line retained the five digits on each hand and foot which we must expect to find in all the ancestors of man down to the lobe-finned fishes that started the very useful business of having hands and feet. If space permitted I could review the evidence that hands and feet have been derived from paired fan-like paddles, and the latter in turn from keels and rudders formed from projections of the flattened lower surface of the body, which was roundly triangular in cross-section. In any case, when paired paddles had once been acquired they were, in the lines of the lobe-finned, air-breathing fishes, soon turned to a new use as limbs. These amphibious creatures then began that conquest of the dry land which was one of the great events in the history of man's forefathers.



At first the early four-footed ancestors of man had to deposit their eggs in the water, but eventually they learned, so to speak, to enclose the eggs in a shell and later to eliminate the shell and nourish the young within the body of the mother. By this time they had attained the grade of mammals and were able to run instead of crawl. About the time of the later dinosaurs the mammals began to climb up into the trees and the common opossum is a "living fossil" from this earliest tree-living stage of existence. But early in the Tertiary Period, or Age of Mammals, a certain branch of the mammals acquired a new mastery of the technique of rapid locomotion in the trees and we have the oldest known fossil Primates of the Eocene epoch. Going on to still more daring ways, certain primitive anthropoid apes learned the trick of brachiating, or swinging by the arms and leaping through the air. The modern gibbon is probably a somewhat over-specialized virtuoso in this art, but our own ances-

FIG. 5. STRUCTURAL SERIES OF SKELETONS FROM FISH TO MAN

I. Devonian lobe-fin (*Eusthenopteron*).
II. Carboniferous amphibian (*Eogyrinus*).
III. Primitive Permo-Carboniferous reptile (*Scymouria*).
IV. Progressive Triassic pro-mammal (*Cynognathus*).
V. Primitive mammal (*Opossum*).
VI. Primitive lemuroid Eocene primate (*Notharctus*).
VII. Proto-anthropoid (*Gibbon*).
VIII. Typical anthropoid (*Chimpanzee*).
IX. Man.

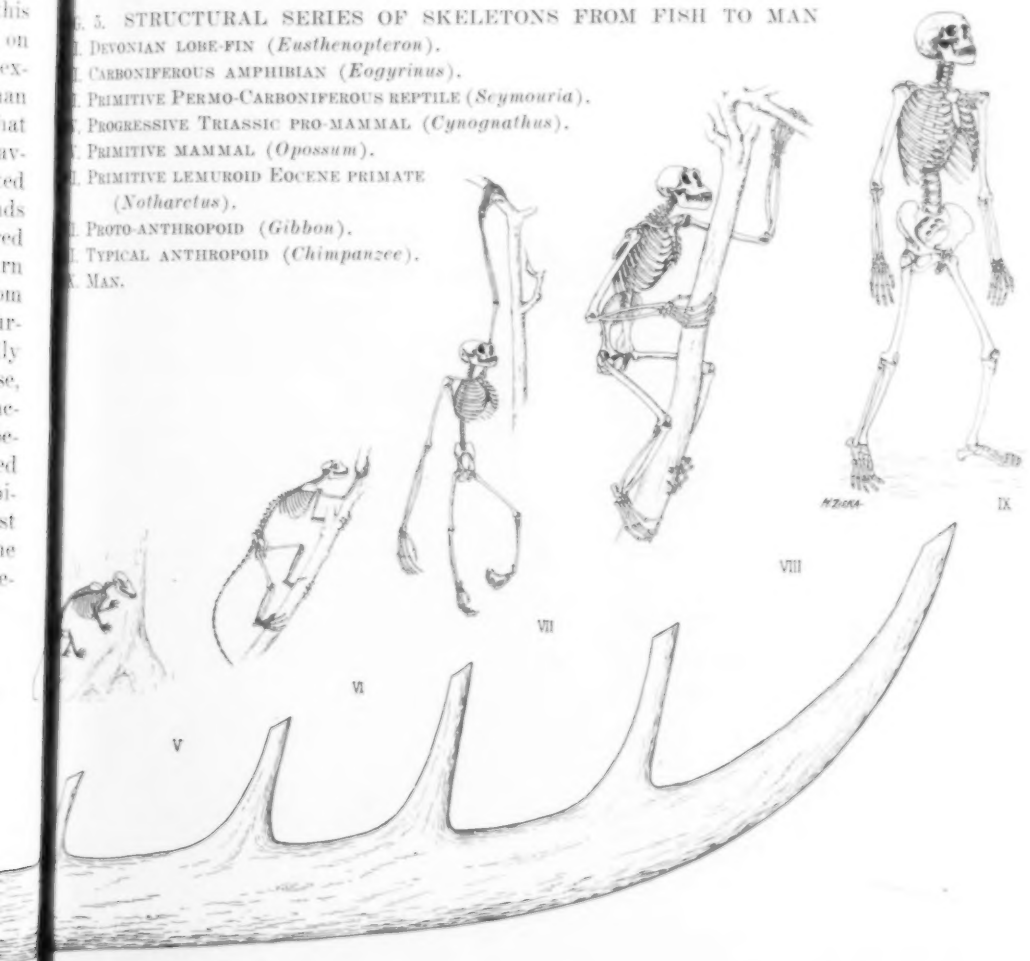


FIG. 6. SKELETON OF GIBBON FROM THE EAST INDIES

THE APE THAT SOLVED THE PROBLEM OF WALKING UPRIGHT.

tors must have learned at least the rudiments of it.

For reasons that can only be conjectured, some of the anthropoid apes then began to spend more and more time upon the ground. Finally some of their descendants found themselves out on the plains, with possibly the habit of rearing up to look over the grass tops. In any case, there is the most abundant and convincing anatomical evidence that man, who for perhaps a million years or more has walked erect, traces his ancestry back to arboreal apes with grasping feet. The important thing to note now, however, is that this momentous transformation involved the lengthening of

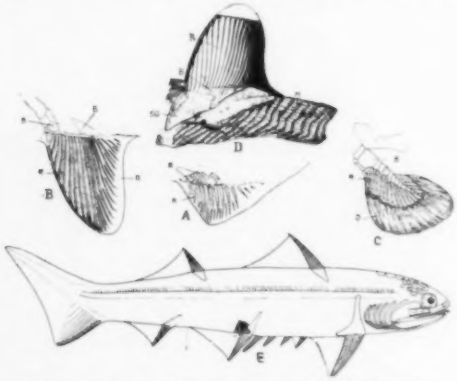


FIG. 7. PROGRESSIVE STRUCTURAL STAGES IN THE FINS OF PALEOZOIC SHARKS

AFTER DEAN.

A. VENTRAL FINS OF DEVONIAN SHARK (*Cladoselache*), SHOWING SEPARATE ROD-LIKE SUPPORTS OF "FIN-FOLD" FIN. B. PECTORAL FIN OF *Cladoselache*, SHOWING PECTORAL GIRDLE AND BASAL PIECES PRESUMABLY DERIVED FROM FUSION OF SEPARATE RODS. C. PECTORAL FIN OF PERMIAN *Pleuracanthus*, SHOWING FULLY DEVELOPED PADDLE-LIKE FIN WITH JOINTED AXIS. D. PECTORAL FIN OF *Cladoselache*, PARTLY COVERED BY PRESERVED MYOMERES. E. RESTORATION OF GENERALIZED ACANTHODIAN BY DEAN.

the hind limbs in man and many other changes in the relative proportions of his thumb, great toe, hip bone, etc.

The history from fish to man is epitomized in a series of paintings by F. L. Jaques (Fig. 8) brought together under the heading, "Students in Nature's

7. Below: A lemuroid primate (Notharctus). An early stage in the evolution of the primates, with hands and feet thoroughly adapted for grasping the limbs of trees.
8. Above: Miocene anthropoid (represented by Chimpanzee). Although now somewhat overspecialized for arboreal life, these apes retain many characteristics which appear to be inherited from the remote ancestors of apes and men.
9. Above: Neanderthal Cave Man. An ancient and extinct human species which retained certain ape-like characters in the skull, braincast and feet.
4. Below: Primitive terrestrial reptile (Seymouria) whose skeleton retained many characteristics of the older amphibians, but adaptations for land-living were progressing.
6. Above: Archaic mammal (Opossum) illustrating an early stage of adaptation to arboreal life.
5. Above: Cynodont reptile (Cynognathus). A marked approach toward the mammalian grade of organization is observed in the entire skeleton.
1. Below: Primitive ganoid fish (Cheirolepis), in which locomotion in the water was effected by undulation of the body.
2. Above: A lobe-finned fish (Eusthenopteron) from the Upper Devonian of Canada. The pectoral and pelvic fins have become strong paddles.
3. Above: Generalized amphibian (Diplovertebron), a primitive fossil amphibian. At this stage five-toed hands and feet had been evolved.

FIG. 8. STUDENTS IN NATURE'S TRAINING SCHOOL

A SERIES OF PAINTINGS BY F. L. JAQUES, ILLUSTRATING THE PRINCIPAL STAGES, FROM FISH TO MAN, IN THE EVOLUTION OF THE LOCOMOTOR APPARATUS AND THE DEVELOPMENT OF THE UPRIGHT POSTURE.

Training School." Without at all subscribing to the Lamarckian doctrine, we may recognize the fact that one kind of environment after another was mastered on the long road upward and that man has inherited both in his anatomical make-up and in the simpler patterns of his nervous reactions some of the more fundamental adjustments learned in earlier environments. For example, his semi-circular canals have served him

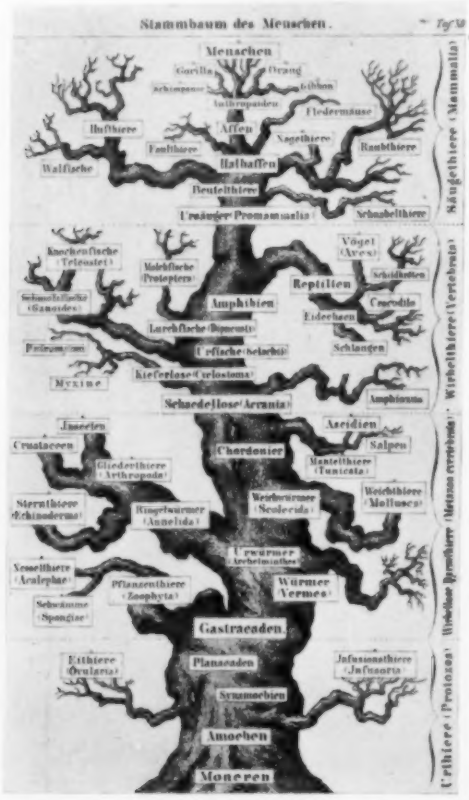


FIG. 9. HAECKEL'S CHART ILLUSTRATING THE PEDIGREE OF MAN

from the fish stage onward with relatively little change, while the paired paddles have been made over into jointed stilts.

So much for the general outline of evolution from fish to man.

The question of the origin of man has always been closely tied up with the question, "Which are man's nearest living relatives?" The earlier anthropogenists, including Darwin, Haeckel and Huxley, did not hesitate to accept the existing anthropoid apes as being the specialized descendants of the common ancestors of apes and man. That this conclusion was correct has been confirmed by thousands of special investigations in many fields. In Haeckel's chart (Fig. 9) man is for convenience placed at the center of the tip of the tree, although Haeckel was anything but anthropocentric in his teachings. In a wall painting (Fig. 10) which we recently installed in the American Museum of Natural History mankind is shown as a curious side-shoot from the anthropoid stock, distinguished by a marked change in his locomotor habitus. His nearest living relatives are there pictured as the chimpanzee and the gorilla.

The general position of man in geologic time is indicated in the chart shown in Fig. 11, which is based on the researches of many vertebrate paleontologists. Here we see that long before the close of the Paleozoic era, some two hundred million years ago, the reptilian stock had already given off a great side branch, the mammal-like reptiles, one group of which eventually gave origin to the mammals. The monotremes, the multituberculates and the marsupials are earlier branches. The placentals are not known until Upper Cretaceous times, near the close of the so-called Age of Reptiles. By Lower Eocene time the placental mammals were already represented by known ancestors of horses, cattle, carnivores, insectivores, etc., as well as by a host of wholly extinct forms. The earliest primates—primitive lemuroid and tarsioid forms—also date from the Lower Eocene; monkeys and apes date from the Oligocene. Man, however, is not represented by admitted flint artifacts until late in the Pliocene. Thus so

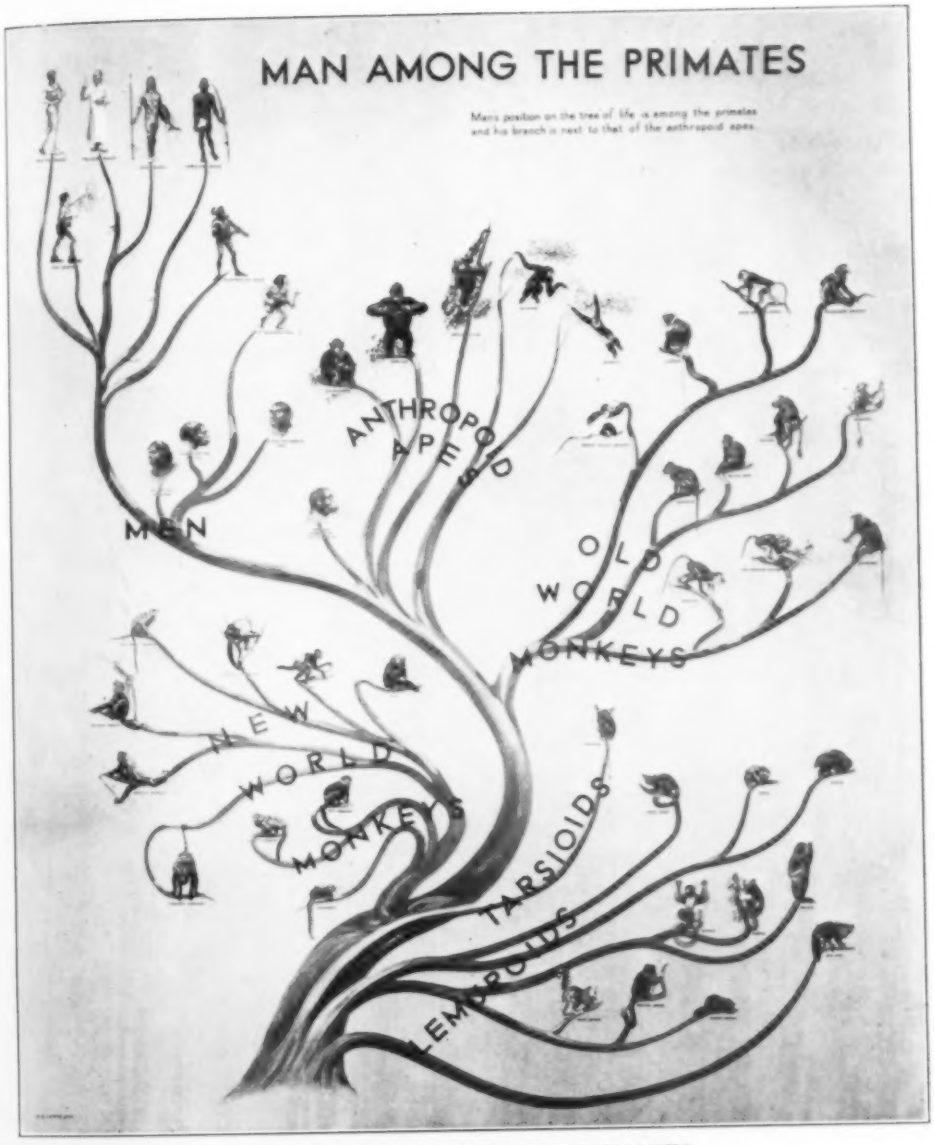

MAN AMONG THE PRIMATES
Man's position on the tree of life is among the primates and his branch is next to that of the anthropoid apes.
MEN
ANTHROPOID APES
OLD WORLD MONKEYS
NEW WORLD MONKEYS
TARSIOIDS
LEMUROIDS

FIG. 10. MAN AMONG THE PRIMATES
(WALL PAINTING IN THE AMERICAN MUSEUM OF NATURAL HISTORY).

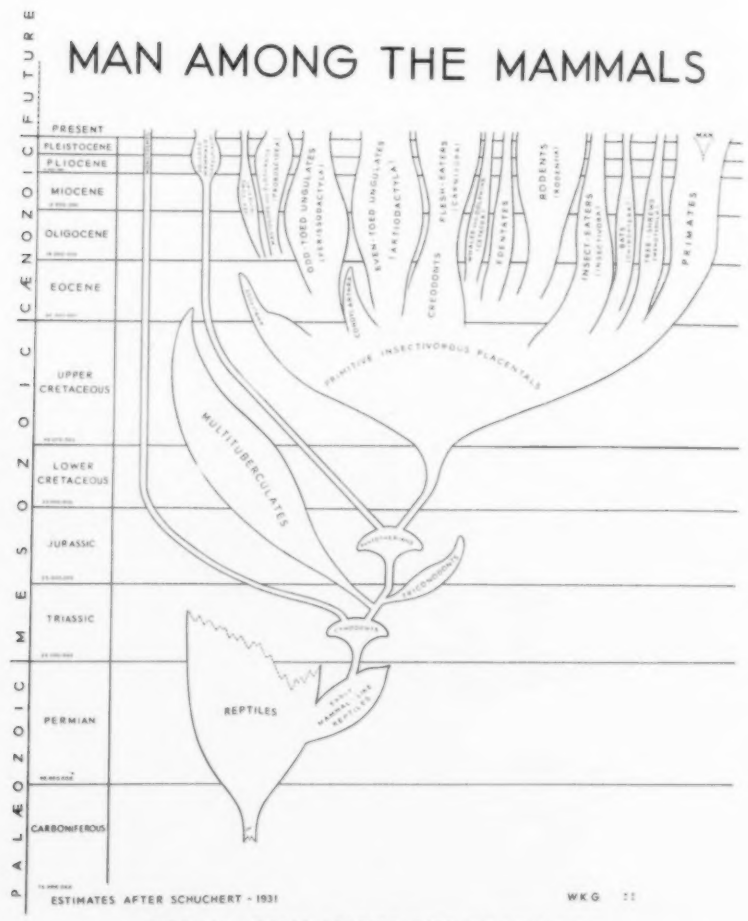


FIG. 11. MAN AMONG THE MAMMALS

far as the record goes it affords no support for those who postulate the separateness of man in early Tertiary times.

The more exact time when the parting of the ways between the nascent Hominidae and their simian relatives took place is still in dispute. Some, like Professor Osborn, believe in the separateness of mankind in early Tertiary times, possibly even in the Lower Eocene. At the other extreme we have Professor Weinert of Germany and Dr. Broom, the eminent paleontologist of South Africa, who date the separation not earlier than in the late Pliocene epoch. I have maintained that the date of the separation of the two families is far less certain than the fact that the separation once took place. The existence of a wide range of fossil anthropoid apes from France to India during late Tertiary times and the fact that some of them are difficult to distinguish in tooth and jaw structure from certain human types, suggest that the separation may already have been under way in late Miocene times, perhaps ten million years ago.

The human foot has afforded great comfort to those who want to separate man as widely as possible from the an-

thropoid apes, for it is obvious that the ape foot is a grasping, tree-climbing type, with a sharply off-set great toe, whereas the human foot is adapted for bipedal erect progression and the great toe is nearly parallel with the remaining toes. There is, however, a great deal of anatomic evidence for the view that the human foot has been derived from an ape-like type chiefly by the drawing together of the great toe and the other toes, which have at the same time become bound together by connective tissue. This tissue has eventually formed the deep transverse metatarsal ligament that ties the great toe to the others.

In spite of its obvious differences the human foot shares with the anthropoid foot a fundamental dichotomy, since the great toe, although tied in with the other toes, yet contrasts widely with them in size and strength. To make a long story short, it can only be said that in beautiful dissections of the feet of various anthropoids and man my colleague, Mr. Raven, has supplied the most cogent evidence that the human foot shares with that of the anthropoid ape a striking unity of plan joined with modifications in proportions and in details appropriate to its newer method of locomotion.

FIG. 12. SKELETON OF FOOT OF GORILLA AND OF MAN (VOLAR ASPECT)

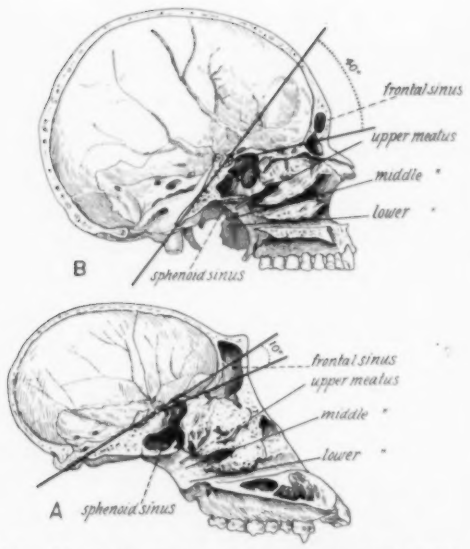


FIG. 13. LONGITUDINAL SECTION OF THE SKULL IN MAN (B) (AFTER CUNNINGHAM) AND CHIMPANZEE (A).

The skeleton of the human hand is built upon the same plan as that of the chimpanzee, save that in man the thumb is larger and the hand as a whole wider. The gorilla hand shows the effect of giantism in widening. To me the evidence suggests that in man the thumb has become markedly enlarged and the hand as a whole shortened and widened. In any case it is a fact that in the anthropoid apes the anterior extremities are true hands rather than fore feet, so that in this respect, as in so many others, the anthropoids anticipate man.

A comparison of half-sections of the skull, along the sagittal plane, of chimpanzee and of man brings out first the agreement in fundamental plan and secondly the expansion of the braincase, the shortening of the upper jaw and vertical expansion of the nasal cavity in man. What more favorable starting-point for the human cranium than the chimpanzee skull could be asked for?

FIG. 14. UPPER AND LOWER TEETH OF *AUSTRALOPITHECUS*

NATURAL SIZE. DRAWINGS BASED ON CASTS AND PHOTOGRAPHS, THE LATTER KINDLY SUPPLIED BY THE DESCRIBER OF *Australopithecus*, PROFESSOR RAYMOND A. DART. THE HINDERMOST TEETH ARE PERMANENT MOLARS; THE OTHERS ARE DECIDUOUS TEETH.

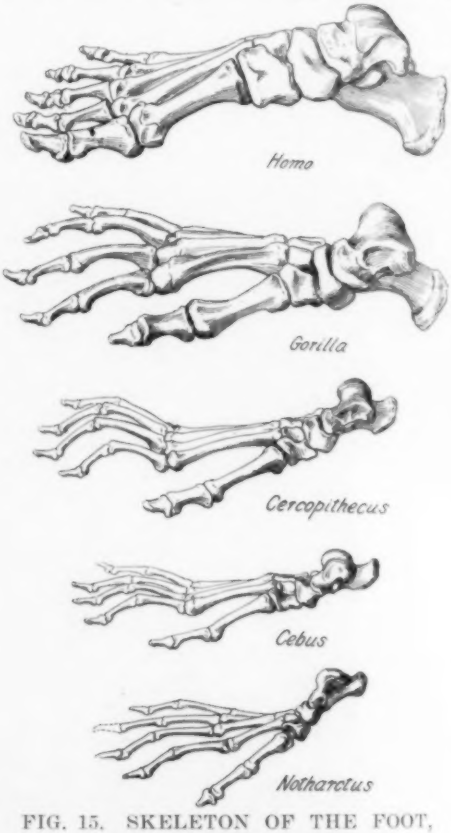


FIG. 15. SKELETON OF THE FOOT, *NOTHARCTUS* TO MAN

The same story is told by a comparison of the brain, as shown in the figures in Professor Tilney's work on "The Brain from Ape to Man." The human

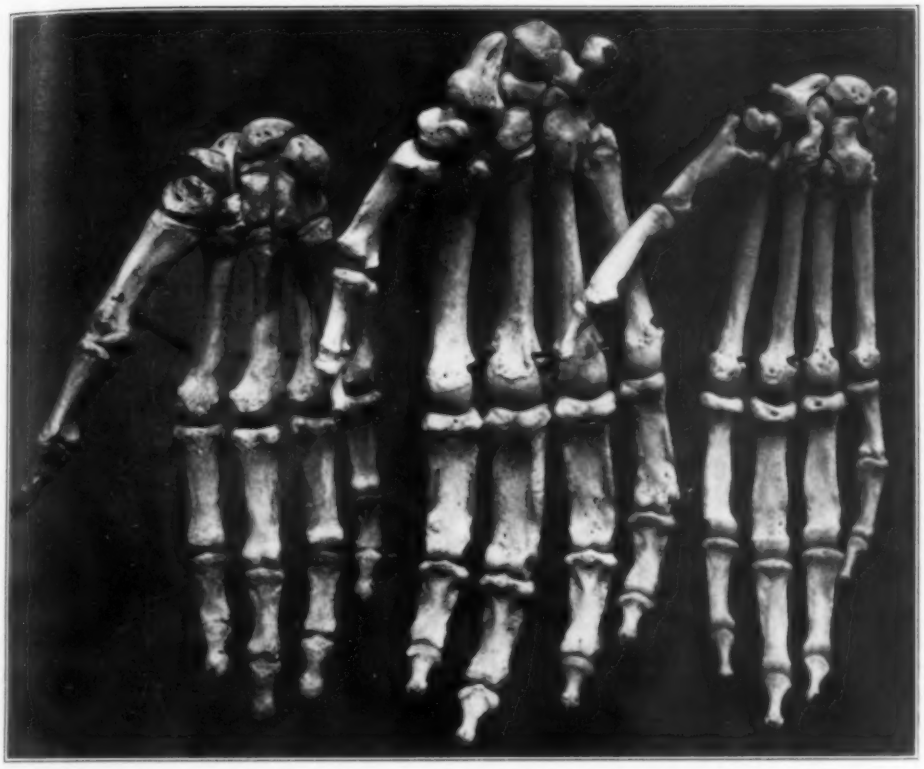


FIG. 16. SKELETON OF HAND OF MAN, GORILLA, CHIMPANZEE (PALMAR ASPECT)

brain is evidently much larger and has a more complexly folded surface than the gorilla brain. The identity in plan of these two brains is even more clearly shown in the basal aspect of the gorilla and human brains. It would be difficult to find a more striking example of agreement in fundamental pattern accompanied by uneven expansion of certain areas in the more advanced type. The same principle is illustrated in cross-sections of the cerebellum of gorilla and man, from Tilney (Fig. 17). Even the nucleus dentatus is strikingly similar in the two forms. From a taxonomic viewpoint such numerous and striking identities in basic patterns can only mean relatively close relationships between the forms compared.

If space permitted I could cite literally hundreds of such agreements between man and one or another of the anthropoids exhibited throughout the skeleton and soft anatomy or in various physiological reactions. This close relationship is especially marked in the fossil *Australopithecus* from South Africa, described in 1925 by Professor Raymond Dart and more recently by the eminent paleontologist, Dr. Robert Broom. A careful study of the details of the deciduous and permanent teeth by my colleague, Dr. Milo Hellman, and myself convinced us that *Australopithecus* in many features of its dentition comes nearer to man than does any other known fossil ape, and that, taken in conjunction with the anatomical evidence

from recent forms, it tends to support the view that the separation between the Hominidae and the Simiidae took place at a relatively late geological epoch. *Australopithecus* tends also to support the view of the late Professor Bolk of Amsterdam, which was that in some respects modern man is a sort of infantilized anthropoid with small jaws and still more swollen brain and braincase.

This leads us at once to the predominant rôle of the brain in human evolution. If we consider the structure and behavior of such a relatively primitive organism as *Peripatus*, we shall note that it moves toward its food, in order, as we say, to seize and eat the food. But please notice that this action appears from our point of view to be directed toward future results, which are the digestion and assimilation of the food and the storage of energy for the running of the vital machinery. While practically all vital reactions have this sort of reference to events in the future, we may also say that a nervous system is of special service in accelerating such adjustments to future situations. In other words, from this point of view a nervous system is on the whole a peculiarly anticipatory or forward-looking system, which prepares for events before they happen. The reason, of course, why actions can be successfully adjusted

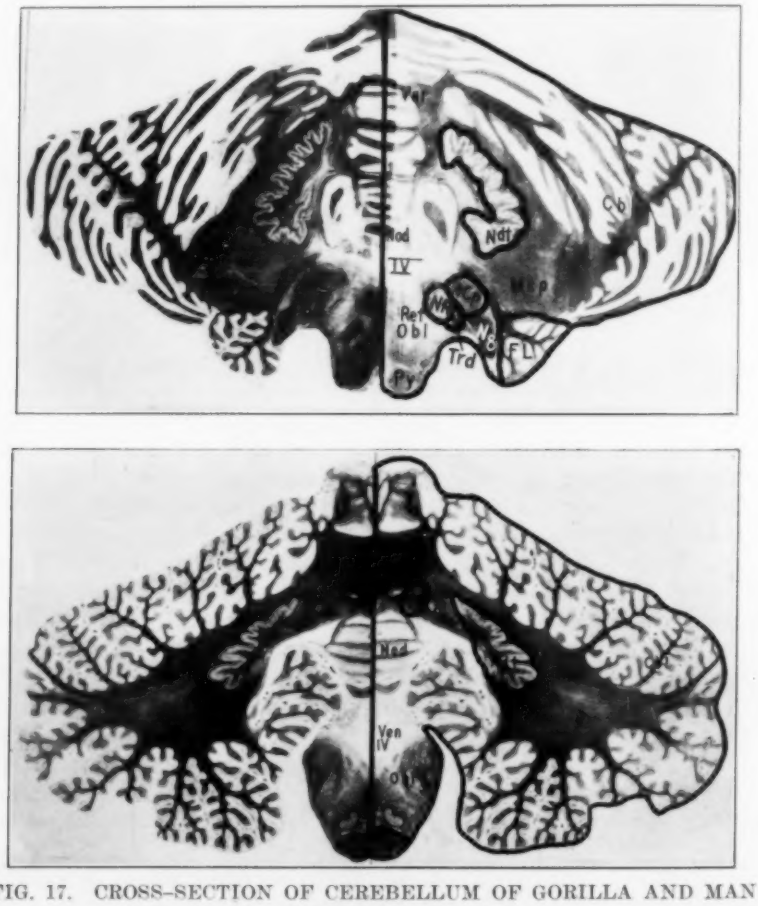


FIG. 17. CROSS-SECTION OF CEREBELLUM OF GORILLA AND MAN
AFTER TILNEY.

FIG. 18. *AUSTRALOPITHECUS AFRICANUS*
AFTER DART.

to future events is that in a world of day and night and regular seasons future events in the long run are apt to average about the same as past events, so that by at first adjusting themselves to what *has* happened, creatures with nervous systems learn to pick out the signals of events that are about to happen, and finally by natural selection, or what you will, they come into the world wound up to adjust themselves to certain ranges of stimuli.

Paleokinesis, the more direct response to sensory stimuli, is illustrated in the central nervous system of the shark, while neokinesis, the highly indirect and complicated response to sensory stimuli, is illustrated in the functional relations between the neopallium and the older parts of the brain in man. I merely wish to emphasize the idea that with the invention of verbal signals the original simple anticipatory response of the primitive vertebrate became complicated to such a degree that it shifted the evolution of man into wholly new and astonishing patterns. Gone was the age of innocence and simple homely pleasures; selfishness and above all, self-esteem, were magnified and distorted into folly and wickedness. Conditioned responses built up into traditions often

became elaborated into fictitious or conventionalized taboos and other systems of values that have left in them little of the natural relations. The Central Australian native, decked for some ceremony deeply significant to him, pays but little attention to the discomfort of being thickly covered by masses of white clay and vegetation. He probably believes he is a rain god or something of the sort and experiences a grand uplift of "face."

Hence it comes about, through the power of the written and spoken word, that for sheer mass stupidities the like of *Homo sapiens* has never before been seen in an astonished world of reasonably straightforward and honest animals. The only redeeming feature is that often one mass stupidity cancels another, or at least holds it in check.

In spite of all these signs of gradual decline I would not argue that *Homo sapiens*, like Hogarth's flirtatious maid, is tottering to his fall. He may eventually lose his third molars, while his lateral incisors and the terminal joint of his little toe may disappear; he may have adenoids, contracted palate and bad teeth. On the other hand, his brain may become even more swollen (but only if Caesarian operations become common). On the whole, however, as Professor Tilney has noted, it is far more important for him to make better use of the cauliflower-like organ that he already has.

With all his afflictions and stupidities *Homo sapiens* is distributed nearly all over the map, and experience shows that no other animal is so difficult to exterminate permanently. The Chinese for ages have been afflicted with floods, war, famine, pestilence and the native pharmacopeia, but for all that there are still enough Chinese to worry the Japanese.

In short, I have never seen any sufficient reason for assessing *Homo sapiens*, or *Homo* of some new species, as a bad insurance risk for a few million years more, which is but a short period in the history of a genus. Not all the human race will succeed in slaying each other with gas or germs and there will still be relatively honest and unsophisticated folk in Asia or Africa whose descendants will move in and possess the land in their turn.

ARTHROPODS AND THEIR RELATIONSHIP TO DISEASES OF DOMESTIC ANIMALS

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PATHOGENIC bacteria have held the stage of public attention for so many years that they have, to a considerable extent, overshadowed the importance of other organisms responsible for sickness and death. This is particularly true of the biological relationship between insects and insect-borne diseases of man and domestic animals.

Of the various diseases to which domestic animals are susceptible, a surprisingly large number are transmitted by insects or other arthropods, either mechanically, as by carrying infective material on their biting mouth-parts, or by the fact that they act as intermediate hosts for the complete development and continuity of certain disease-producing organisms.

It is interesting to note that a number of diseases of animals can be transmitted only through the instrumentality of specific arthropod hosts. For instance, there are many species of ticks infesting wild and domestic animals, yet there is only one species—at least on this continenf—that is capable of transmitting the disease of cattle commonly known as "Texas fever."

If it were not for certain insects known to be carriers of infection, a number of diseases of domestic animals could not and would not exist. This knowledge is of great importance and practical value, because it enables the veterinarian, live-stock sanitation and owner to control, and in many cases to eradicate a number of diseases of animals, by attacking or destroying arthropods responsible for their transmission.

The species of arthropods responsible for the transmission or spread of animal diseases is quite large—too large in fact to discuss in detail in an article such as this, a general review of species that are of particular interest to persons who are directly or indirectly connected with or interested in the live-stock industry in one or more of its various branches. What may be facetiously termed "the rogue's gallery of insects" is herein presented with some semblance of zoological order.

CRUSTACEANS

Crustaceans are not a very important group of arthropods so far as the transmission of animal diseases is concerned. However, they can not be entirely ignored, because some species serve as intermediate hosts for a few helminth parasites of animals. For instance, certain species of crabs and cyclops (*Copepoda*) are intermediate hosts of various species of tapeworms that infest ducks, geese and other aquatic birds. Cyclops are also indirectly responsible for the transmission of a species of tropical roundworm called "the Guinea or Medina worm" (*Dracunculus medinensis*), which invades the subcutaneous tissues of hogs, horses, cattle, sheep, goats and man. The infestation of animals is brought about by drinking water containing cyclops, the bodies of which contain embryo worms. Guinea worms are of far more medical importance to man than to the lower animals.

Another crustacean, known in the United States as "the sow bug" and in

England as "the wood louse," has been found to be the intermediate host of the spiral stomach worm of chickens (*Dispharynx spiralis*). This worm, found in the tissues of the glandular stomach of chickens, turkeys and pigeons, does a considerable amount of damage. In game birds, two sow bugs, namely, *Porcillio scaber* and *Armidillium vulgare*, serve as intermediate hosts for the spiral stomach worm—the same species that infests chickens.

Insects

Insects, as would naturally be expected because of their relatively large numbers, form the major portion of the arthropods affecting domestic animals. Six orders of insects are included in this category, namely: Odonata (dragon-flies); Malophaga (biting lice); Orthoptera (roaches, etc.); Diptera (flies); Siphonaptera (fleas); and Coleoptera (beetles).

Odonata (dragon-flies): Dragon-flies, snake doctors, devil's darning needles, etc., are a few of the "charming" names given to this order of useful insects. They are of little importance as disease vectors, although Kotland and Chandler have reported that dragon-flies were intermediate hosts of a newly discovered species of fluke (*Prosthogonimus* sp.), which inhabit the oviducts of poultry. These investigators found encysted larvae of this fluke in adult dragon-flies and in their nymphs. Experimental proof that dragon-flies are capable of transmitting flukes was demonstrated by feeding birds infested dragon-fly nymphs, after which adult flukes were found in the oviducts of these birds.

Malophaga (biting lice): Many people who own pets (and possibly many who do not) are familiar with the discomfort produced by biting lice. The ill effects resulting from lice in domestic animals are not entirely due to irritation; there are several species that are of considerable importance as carriers of certain animal diseases. For instance, the rabbit louse (*Haemodipsus ventricosus*), is known to transmit tularemia to both man and lower animals. There is also evidence that the short-nosed louse of cattle (*Haematopinus eurysternus*) is capable of transmitting anaplasmosis—a disease of cattle caused by a protozoan parasite which invades the red blood cells. At least Stiles was able to produce the disease experimentally in a young guinea-pig by injecting it with macerated bodies of lice taken off cattle suffering from anaplasmosis. Other arthropods, chiefly ticks, are thought to be principally responsible for the transmission of this disease.

One of the two species of lice that are commonly found on dogs, namely, the biting louse (*Trichodectes latus*), is of particular interest because it is one of the intermediate hosts of the double-pored tapeworm of dogs (*Dipylidium caninum*), which inhabits the small intestine, and also because it was the first arthropod recognized to be the intermediate host of a parasitic worm. Lice become infested with larvae of this dog tapeworm by swallowing them while feeding on the contaminated skin of dogs. Dogs in turn become infested by swallowing lice containing encysted embryo tapeworms or larvae, usually at the time they are biting themselves to allay irritation.

It might be of interest to state that the double-pored tapeworm of dogs occasionally develops in man, particularly in children, who become infested by accidentally swallowing infested lice, which presumably get into their mouths while fondling dogs, or possibly by placing their fingers in their mouths; or the infestation may be conveyed by food or water. It can then be seen that while "Junior and Towser" may represent an

ideal bond of friendship, this may not always be to Junior's advantage. However, infestation by this dog tapeworm is so rare in man as to be of little concern, although it is always advisable to be on the watch. Aside from the slight risk of transmission to some member of the family, treatment should be given for the elimination of tapeworms in dogs whenever they are found to be infested.

Besides the biting louse, the flea is an intermediate host of the double-pored tapeworm of dogs. This will be discussed later.

Orthoptera (grasshoppers, cockroaches, etc.): One would hardly suspect grasshoppers of having any connection with the transmission of disease. However, not only grasshoppers, but cockroaches serve as intermediate hosts for at least six species of parasitic roundworms of domestic fowl and game birds. Two species of grasshoppers, *Melanoplus femurrubrum* and *M. differentialis* (and probably a number of others), serve as intermediate hosts for *Tetrameres americana*, a roundworm inhabiting the glandular stomach or proventriculus of chickens; also for the spiral stomach worm (*Cheilospirura hamulosa*) of chickens, and (*C. spinosa*) of gallinaceous birds. Cockroaches also play the rôle of intermediate hosts for at least three species of roundworms of poultry and game birds.

The tropical cockroach (*Pycnoscelus surinamensis*), which ranges (under natural conditions) as far north as the Carolinas, serves as intermediate host for a curious worm called "Manson's eye worm" (*Oxyspirura mansoni*), which is found under the nictitating membrane of the eyes of chickens. So far this worm is chiefly confined to the states of Florida and Louisiana, but with the help of accommodating cockroaches and modern transportation facilities it may have an opportunity to travel farther afield.

The European cockroach (*Blatta germanica*) has recently been found to be the intermediate host for a parasitic roundworm, technically known as *Seurocyrnea colini*, which invades the wall of the glandular stomach or proventriculus of game birds. According to Dr. Eloise B. Cram, this worm has not been reported from any other country than the United States.

Diptera (true flies): Flies are undoubtedly one of the worst pests that wild and domestic animals have to contend with. Not only do flies cause continuous torment to animals during the warmer months, but they are also responsible for the transmission of a number of specific animal diseases, while the larvae of a number of species produce extensive and often fatal wounds by feeding on skin, flesh and other tissue.

Several species of flies are of considerable economic importance as intermediate hosts for parasitic worms; for instance, two or more species of poultry tapeworms (*Choanotaenia infundibulum* and *Davainea cesticellus*) are transmitted by the common house-fly. In horses, three species of stomach worms, *Habronema muscae*, *H. megastoma* and *H. microstoma*, are transmitted by flies. The first two pass their larval stage in the grubs or larvae of house-flies, while the latter is transmitted directly by the stable-fly (*Stomoxys calcitrans*).

Flies belonging to the order Muscidae are represented by a number of very harmful species. None, however, are of more historical, economic or medicinal importance than the well-known tsetse flies which are responsible for the transmission of African sleeping sickness—a disease which renders vast areas of Central and West Africa uninhabitable. The African type of sleeping sickness

(which should not be confused with the so-called sleeping sickness or encephalitis of temperate climates) is caused by an elongated microscopic animal parasite (trypanosome), which invades the blood stream.

This parasite is principally transmitted, at least in Africa, by various species of tsetse flies on which it depends for the completion of its life cycle and its transmission to other susceptible victims. Both trypanosomes and tsetse flies are of particular interest in medical history because the cause of African sleeping sickness was not clearly understood until Sir David Bruce, in 1896, discovered that nagana,[1] an African disease of horses, mules, cattle and other domestic animals, similar to the human type of infection, was caused by a trypanosome parasite in the blood. This parasite was later named in his honor as *Trypanosoma brucei*. By patient observation Sir David also discovered that nagana was spread by the tsetse fly (*Glossina morsitans*) from sick to healthy animals. Armed with this knowledge the cause of the human type of trypanosomiasis was a matter of comparatively easy solution.

There are several types of trypanosomiasis in both man and animals, all of which are transmitted by tsetse flies. However, as the general characteristics and method of spread of the various types of trypanosome infection are more or less alike, there seems little need to go into further detail.

Trypanosome infections of animals are not always transmitted by tsetse flies. In India and the Orient, a disease called "surra," affecting horses, mules, camels, elephants and other wild and domestic animals, is transmitted by several species of horse-flies or tabanids. Murrina of mules in Central America and *mal de caderas* (disease of the hindquarters) in South America are both caused by trypanosomes and are transmitted from one animal to another by horse-flies and other blood-sucking diptera. One genus of horse-flies, namely, *Chrysops* (deer-flies), is responsible (together with several other species of arthropods) for the transmission of tularemia. Wild rabbits are thought to be the principal reservoir of infection, and wood-ticks are the principal carriers.

Aside from the transmission of infectious diseases by diptera, several species of muscid flies are of tremendous economic importance because they do considerable damage in their larval stage.

Those who have lived in rural sections of the southeastern United States are probably familiar with the grubs or larvae of the screw-worm fly (*Chrysomyia macellaria*), which inflicts such terrible wounds on various species of live stock. The female screw-worm fly lays her eggs on or near cuts or abrasions on the body. It only requires a few days for these eggs to hatch into grubs, which immediately commence to burrow into sound tissue. The discharge of bloody serum from the infected parts enables the owner or his assistants to easily detect the presence of screw-worms.

There are a number of other muscid flies, known collectively as "blowflies," which are of considerable economic importance to live-stock owners, particularly to sheep-raisers, because they lay their eggs on soiled wool, chiefly around the vent or hindquarters. The larvae of these flies live on the soiled wool and in the flesh, causing the fleece to become of little commercial value. In addition to this, the loss of time and expense in picking out and treating infested sheep adds considerably to the cost of production.

[1] According to Sir David Bruce, "nagana" is a Zulu word which refers to the state of depression and weakness characteristic of the disease.

Two other muscid flies, known as ox warbles and gadflies (*Hypoderma lineata* and *H. bovis*), cause an annual loss of approximately fifty million dollars in the United States, according to an estimate made by the U. S. Department of Agriculture. The principal damage results from holes made through the hide of the animal by the larvae in working their way out. The life cycle of warble flies is rather complicated, but very interesting. Briefly, the eggs are generally laid on hairs on or near the heels of cattle. The grubs soon hatch, after which they penetrate the skin and work upwards through the tissues of the body until they finally reach the back. Here swellings are produced, through the top of which the larva cuts a hole and finally emerges and falls to the ground, to change to pupa or chrysalis, emerging as an adult fly the following summer.

The holes in the skin naturally cause the hides to be of little value for the manufacture of leather, but this is not the only source of loss; the female flies in depositing their eggs frighten the cattle so much that many are injured during stampedes, running into trees or other objects, breaking their legs, falling off cliffs, etc.

The northern gadfly (*Hypoderma bovis*), while not so common or so widespread in range as *H. lineola*, nevertheless causes a greater degree of excitement in cattle while attempting to deposit eggs on hairs on the heels of its bovine victim. This, no doubt, is due to the fact that its attack is more vicious and the noise of its rapidly moving wings is of a higher pitch.

In Alaska and other parts of the northern hemisphere, reindeer are attacked by another gadfly (*Oedemagena tarandi*), the larvae of which emerge through holes in the skin of the back, like the larvae of the gadflies of cattle. Apparently the reindeer fly was introduced into Alaska by the importation of reindeer from northern Europe.

In Russia, a gadfly (*Rhinoestrus nasalis*) parasitizes the nasopharyngeal region of horses. It may also attack man. When this occurs it is said to deposit its eggs almost instantaneously in the eyes. The larvae cause intense pain and conjunctivitis, and if not removed before too much tissue damage has resulted, permanent blindness may follow.

In tropical America we also have another curious and enterprising representative of the gadfly family in *Dermatobia hominis*. The female of this species, instead of laying eggs in the usual orthodox manner, catches mosquitoes and blood-sucking flies and attaches eggs to the sides of their bodies. As soon as the victimized insects alight on cattle to feed on their blood, the eggs, stimulated by the warmth of the animal's body, hatch almost immediately, and the young grubs transfer themselves from their temporary insect host to the skin of their final host, through which they burrow. Lumps or tumors are produced by the larvae on the animal's back, through the top of which holes are cut similar to those produced by the larvae of the cattle gadfly. The remainder of their life cycle is about the same as that of other species of gadflies.

Another example of harmful fly larvae is to be found in the bot-flies (*Gastrophilus*). The larvae of bot-flies inhabit the stomach and digestive tract of horses, mules and other species of equidae. In the United States there are three species of bot-flies, namely, *Gastrophilus intestinalis*, *G. nasalis* and *G. haemorrhoidalis*.

The eggs of bot-flies are laid on hairs on different parts of the body, the area selected being characteristic of the species which lays them. In depositing eggs, the female fly produces a humming noise with her wings, which, in the case

of the nose bot-fly (*G. haemorrhoidalis*) and the throat fly (*G. nasalis*), causes considerable excitement in horses; in fact, nervous animals frequently become unmanageable, with the result that "runaways" and accidents are of common occurrence during the fly season.

The larvae of bot-flies get into the digestive tract of horses and mules when the animals bite or lick themselves. However, in the case of the throat bot-fly, it is thought that the larvae penetrate the skin and tissues and finally enter the esophagus and stomach under their own power, as it were.

Bot-fly larvae produce considerable damage after they attach themselves to the mucous lining of the stomach and intestine, by interfering with the digestive functions and also by causing irritation at the place of attachment. Sometimes pus-producing bacteria may enter, causing abscesses which may destroy so much tissue that perforation of the stomach wall follows. In such cases peritonitis invariably develops, terminating in death.

The larvae are easily destroyed by the administration of carbon disulfide during December, January and February. This drug kills not only the bots but also large roundworms or ascarids and stomach worms (*Habronema*).

In Iowa and Illinois, excellent results have been obtained in controlling bots in horses by the cooperative efforts of agricultural extension workers, local veterinarians and horse-owners. The principal object in this work is to treat as many horses and mules in as wide an area as possible so that the bots will be destroyed before they have an opportunity to develop into flies. In other words, it is much easier to control or destroy the larvae than the flies—which are of course able to travel comparatively long distances and deposit thousands of eggs. Horse-owners who have experienced the benefits resulting from community bot-eradication work (call it state medicine, if you will) are very enthusiastic because they realize that treated horses and mules can be kept through the winter in better physical condition and with less feed and consequently much less expense. It may also be said that when a sufficient number of owners have had their animals treated in a certain community, the number of bot-flies will be so reduced as to enable teams to work the following summer without being constantly subjected to attacks of bot-flies. Individual farmers or team-owners at times refuse to enter into a cooperative scheme of this kind. The horses and mules of these recalcitrants serve as incubators for bot-flies, which, not having the power of discrimination, are as likely to lay eggs on the animals of the most enthusiastic public-spirited farmers as on those owned by the "rugged individualists."

In sheep there is another species of bot-fly, namely, *Oestris ovis*, which has somewhat different habits, in that, instead of depositing eggs on the hair or wool, it lays them in the sheep's nostrils. The eggs are ready to hatch as soon as they are deposited, so the young larvae lose no time in working their way up the nose into the nasal sinuses, where they attach themselves to the mucous membrane by means of hooklets. So much irritation is produced by these grubs that more or less characteristic symptoms are exhibited, such as violent sneezing, stamping on the ground, discharge from the nose, loss of flesh, etc.

Simulidae (black flies or buffalo gnats): Readers who are trout fishermen or who camp near streams in the spring will need no introduction to these insects, because their sharp and irritating bites are sufficient to make a lasting impression on the memory. Black flies are a serious menace to live-stock owners during the early part of the year. In

fact, the blood extracted and toxins or poisons injected by these flies cause serious and sometimes fatal sickness, even in larger animals, such as horses, mules and cattle. Black flies are also responsible for the spread of different communicable diseases, so that they are of particular economic importance. In ducks, a disease caused by a protozoan parasite (*Leucocytozoon anitis*) is spread by black flies, according to Dr. E. E. O'Roke, of the School of Forestry and Conservation of the University of Michigan. This disease has caused a considerable reduction in the numbers of wild ducks at Douglas Lake and elsewhere in Michigan, according to this same observer. The parasite is transmitted from sick to well ducks by the bite of black flies. Adult ducks harboring the parasite are apparently little affected, but ducklings succumb in large numbers. Domestic ducks are also affected. Farmers report losses of from 70 to 100 per cent.

Turkeys suffer from a similar disease, which is also transmitted by black flies. The organism in this case is *Leucocytozoon smithi*. It produces symptoms of muscular incoordination, sleepiness, coma, exhaustion and sometimes convulsions.

In horses, black flies are responsible for the transmission of a roundworm (*Onchocera volvulus*), which is associated with a rather common disease of the withers of horses known as fistula. What part this parasite plays in the pathology of fistulous withers (and a similar condition affecting the head, back of the ears, known as poll evil) has not yet been definitely determined.

Blacklock has shown that the microfilaria of *O. volvulus* may develop in black flies; consequently, these insects, together with other diptera, such as tabanid flies, mosquitoes, etc., may be responsible for the transmission and spread of both fistula and poll evil among horses and mules.

Before dismissing black flies or buffalo gnats as vectors of animal diseases, it may be as well to state that anthrax, an exceptionally virulent disease of live stock in many of our southern states, is thought to be carried by these insects as well as by other blood-sucking flies.

Culicidae (mosquitoes): It has recently been discovered that mosquitoes belonging to the genera Culex and Aëdes are responsible for the spread of fowl pox, a very common and harmful disease of chickens and pigeons. Mosquitoes also act as vectors of avian malaria and possibly coccidiosis.

Fowl pox and other diseases are probably transmitted mechanically by mosquitoes—differing in this respect from the transmission of human malaria, which requires the completion of the sexual cycle of the malaria parasites inside the body of the mosquito before becoming infective for man.

One of the most interesting and important diseases carried by mosquitoes, so far as dog-owners are concerned, is heartworm infestation. Within the last few years dog-owners have become greatly concerned about the rapid spread of these parasites. The first reports of the occurrence of heartworm infestation in dogs in the United States were made from Florida. Now heartworms are found in dogs in states much further north. The spread of this parasite is undoubtedly due to the fact that dogs shipped south for the hunting season become infested and on their return to their northern homes act as centers of infestation for other dogs. As it is only necessary to have infested dogs and the presence of mosquitoes to make outbreaks possible, it will not be at all surprising if heartworm in dogs becomes far more wide-spread than it is at present.

Heartworms in their mature stage inhabit the right half of the heart. The parasite is viviparous, but the embryos are to be found in the general circulation. This is what makes it possible for mosquitoes to take up the embryo worms while feeding on infected dogs and to transfer them to other dogs.

Symptoms produced as a result of heartworm infestation are not sufficiently characteristic as a rule to make a diagnosis easy, but a microscopic examination of the blood from suspected dogs has, of course, diagnostic value.

Up to within a short time ago no cure for canine heartworm infestation was known until Dr. J. M. Hays, of the Alabama Polytechnic Institute of Auburn, Alabama, reported, through the medium of a veterinary journal (*Veterinary Medicine*, April, 1933), that he had found a double antimony salt to produce good clinical results when injected intravenously.

More recently, the Zoological Division of the Bureau of Animal Industry announced that two of their veterinarians, namely Drs. W. H. Wright and P. C. Underwood, had tested the efficacy of a complex antimony compound called "Fouadin" and that it had proved effective as a remedy for heartworm infestation in dogs. This work, I understand, was assisted by a fund raised by the Sportsman's Gun-Dog Club of Philadelphia, so that this organization should receive full credit for their valuable aid.

Major R. A. Kelser, of the Army Medical School, recently discovered that the mosquito (*Aedes aegypti*) is capable of transmitting equine encephalomyelitis, commonly known as "horse plague." This disease is caused by a filterable virus and was first reported in the San Joaquin Valley in California during the summer of 1930. Since that time the disease has become rather widespread and is causing considerable loss to horse-owners.

Hippoboscidae (sheep-ticks): Sheep-ticks, as the reader is probably aware, are not true ticks at all, but degenerate flies living a parasitic life on the bodies of sheep. There are many species of hippoboscid flies, a number of which are found on birds, particularly owls and hawks. The sheep-tick, while a blood-sucker, strangely enough does not transmit any parasite known to be harmful. Nevertheless, in Australia, sheep-ticks are known to transmit a non-pathogenic protozoan parasite (*Trypanosoma melaphagum*), which is only of academic importance to students of parasitology. Sheep-ticks, even though they are not known to transmit disease, are nevertheless a serious menace to sheep-breeders because they cause considerable irritation, restlessness and loss of blood in sheep, which as a consequence rapidly fall off in flesh and in general physical condition.

Another hippoboscid fly, known as the pigeon fly (*Pseudolynchia maura*), causes pigeon-fanciers much trouble and loss. Unlike the sheep-tick, this particular fly is equipped with wings which enable it to make short flights from one bird to another. The pigeon fly is not only of considerable economic interest to pigeon-fanciers because of its irritating and blood-sucking habits, but it is also of importance because it is a carrier of pigeon malaria. This disease causes much sickness and many deaths in pigeons, but its control is confined almost entirely to the eradication of pigeon flies, which are readily destroyed by the application of pyrethrum powder and other insecticides in addition to the frequent cleaning up and removal of droppings, etc.

Another hippoboscid fly similar to the pigeon fly, called *Lynchia hirsuta*, is

found on California Valley quail. This fly also transmits a blood protozoan parasite which causes the death of a great many quail, particularly young birds, which seem to be more susceptible to the disease than older birds.

Siphonaptera (fleas): Fleas are of tremendous importance to the human medical entomologist because they spread bubonic plague, but, so far as the veterinarian and the live-stock owner are concerned, they are (with the exception of the chigoe) of little importance other than that they cause considerable annoyance to live stock. The principal interest in fleas, so far as the transmission of disease in domestic animals goes, is that they act as intermediate host for the double-pored tapeworm of dogs (which is also carried by dog and cat lice, as mentioned in a previous paragraph). Fleas in the larval stage become infested with the embryos of the double-pored tapeworm by swallowing the tapeworm eggs mixed with débris on which the flea larvae feed. The embryo tapeworms are therefore carried over to the adult flea at the time of metamorphosis.

The chigoe (family *Tungidae*) of the Tropics causes a great deal of annoyance and damage to dogs by penetrating the skin between the toes, producing sores similar to those occurring in man from the same source. Professor Frederick Gaige, of the University of Michigan, informed the writer that he had found dogs to be very badly infested with chigoes in Mexico and in Central America. The female chigoe in man usually burrows under the toe nails in order to lay her eggs; while on dogs, as already stated, the flea penetrates the skin between the toes, causing a painful swelling which may become infected with pus-producing bacteria so that serious consequences may follow.

Coleoptera (beetles): While beetles are represented by more species than any other order of insects, they are of little if any importance as vectors of disease other than as intermediate hosts for a rather limited number of parasitic worms that infest animals. One of the most important and interesting occurrences in this connection is the transmission of the thorn-headed worm of swine with the rather awe-inspiring technical name of *Macracanthorhynchus hirudinaceus*, by May-beetles or June-bugs (chiefly *Lachnosterna*). This worm, which seems to occupy an intermediate position between tapeworms and roundworms, attaches itself in its mature form to the mucous membrane lining the small intestines of hogs, by five rows of strong hooks on the head end of its body. As a rule, thorn-headed worms are not ranked as of major importance, but they nevertheless cause unthriftiness and digestive disturbances in hogs. May-beetle grubs ingest the eggs of thorn-headed worms passed out of the body of infested hogs, mixed with the feces. After hatching inside the digestive tract of the May-beetle larvae, the embryo worms become encysted in the muscles, and are released only when the grub or adult beetle is swallowed by hogs. Both May-beetle adults and larvae act as intermediate hosts. Hogs readily become infested because they are very fond of May-beetle grubs and will root up considerable pasture land in their eagerness to find them. Knowing this, hog-raisers often place a ring in the tips of hog's snouts in order to prevent them from rooting—which, whether the owner is aware of it or not, goes a long way to prevent swine from becoming infested.

Certain species of dung beetles also act as intermediate hosts for a rather unimportant roundworm of poultry and game birds technically known as *Gongylonema ingluvicola;* also for a roundworm of the same genus inhabiting the mucous and submucous membranes of the esophagus

of sheep and cattle, namely, *Gongylonema pulchrum* (scutatum). Three poultry tapeworms are also known to be transmitted by various species of beetles, all of which are of more or less economic importance to the poultry raiser.

In addition to the transmission of parasitic worms by beetles, the rose-chafer (*Macrodactylus subspinosus*), causes poisoning in young chickens under ten (10) weeks of age. The symptoms produced are drowsiness, weakness of the legs, paralysis and death. Readers who raise poultry should keep this fact in mind, as it may prevent avoidable loss in case young chickens are kept where there are rose bushes infested with these beetles.

Acarina (Mites and Ticks)

The order *Acarina* contains species of arthropods that are of tremendous importance to the live-stock owner, not alone because many of them cause considerable damage due to their blood-sucking and irritating habits, but because a number of species are carriers of fatal diseases of domestic animals similar in nature to malaria in man. By far the most important tick from an economic point of view in the United States is the southern cattle tick (*Boophilus annulatus*), because it alone of all species in this country is capable of transmitting Texas or splenic fever to cattle. The microorganism causing Texas fever (*Babesia bigeminum*) is a protozoan which invades and destroys the red blood-cells. Texas fever is usually fatal in from 10 to 90 per cent. of non-immune cattle and is one of the principal reasons why cattle-raising has not been more profitable or more highly developed in many of the southern tier of states where the tick is common.

Native cattle that have grown up with ticks, and consequently have been exposed to infection at a very early age, do not usually show any appreciable effect so far as Texas fever is concerned, although they act as reservoirs of infection. The principal damage done to immune cattle is due to the constant irritation by the ticks, and the loss of blood, which may be enormous; for instance, a single female tick may gorge itself on blood until it becomes one hundred times its original size.

The loss in weight and physical condition, shrinkage in milk production in the case of milk cows and death from weakness and exhaustion are the chief forms of damage done by ticks to immune cattle.

The eradication of Texas fever ticks by federal, state and county control measures is one of the most outstanding feats of successfully applied medical entomology in any country. Previous to the initiation of control measures in 1906, Texas fever ticks were to be found ranging as far north as Virginia and as far west as California. In twenty-eight years, federal and state forces have successfully eradicated this parasite from all but comparatively small sections of Florida, Louisiana and Texas. It is expected that if the work continues as rapidly and as successfully as it has in the past the United States will be entirely free of Texas fever ticks within a very few years. Parasitologists who desire specimens of *B. annulatus* had better lay in large series while the supply lasts; otherwise they may have to go to Mexico or to Central America for them.

Aside from the fact that the almost total eradication of the Texas fever tick from U. S. territory is an accomplishment to be proud of, it also has a very illuminating economic side. For instance, in a recent article on Texas fever in the April (1934) issue of *The North American Veterinarian*, Dr. M. C. Hall, chief of the Zoological Division, Bureau of Animal Industry, pointed out that in

1906 it was estimated that Texas fever ticks and Texas fever plundered the people of the United States of $73,000,000 annually. He also pointed out that the total federal and state expenditures for eradication work up to date aggregated $41,679,520, so that the total cost of this work so far is less than the loss sustained *in one year* as a result of the depredations of the ticks and Texas fever.

While the Texas fever tick is alone responsible for the transmission of Texas fever in the Americas, there are other species capable of spreading this disease in other parts of the world. For instance, a subspecies of the Texas fever tick is found in Australia which is capable of transmitting the disease, namely, *Boophilus annulatus, australis.* Curiously enough, a recent check-up has revealed the fact that this particular subspecies is also found in Florida and Texas.

The castor bean tick (*Ixodes ricinus*) is responsible for the transmission of a disease similar to Texas fever in various parts of Europe, while in South Africa the blue tick (*Boophilus decoloratus*) is the vector.

Now that Texas fever has been largely eradicated in the United States, another disease of cattle has sprung up to take its place, namely, anaplasmosis. This disease is caused by an organism so similar to that causing Texas fever that it is only within comparatively recent times that the difference has been realized. Anaplasmosis does not depend on the Texas fever tick for its transmission, as three ticks so far are known to be capable of carrying it. These three are: the dog-tick (*Dermacentor variabilis*), the brown dog-tick (*Rhipacephalus sanguineus*) and the wood-tick (*Dermacentor andersoni*). There is a possibility that other arthropods may be involved in the transmission of anaplasmosis, in which case the disease will be a difficult one to control. Already it is spreading and is causing heavy losses in some of the southern and central states.

The list of ticks responsible for the spread of diseases in animals by means of the piroplasma group of organisms is so great that the reader's patience would be exhausted if an attempt were made to go into detail. However, it might be of interest to state briefly that biliary fever in horses and mules in South Africa and equine piroplasmosis in the same animals in Russia are transmitted by ticks, while East African coast fever in cattle, ictero-hematuria or heart-water disease in sheep and malignant jaundice in dogs are also caused by species of piroplasmas transmissible by various species of ticks.

Tularemia or deer-fly fever is another tick-borne disease which has been given considerable publicity in the press, chiefly because it affects wild rabbits and is easily transmitted to those who handle or dress these animals, such as hunters, butchers, housewives, etc. Tularemia produces in human patients such symptoms as a papule and inflammation at the point of infection, fever, chills, painful swelling of the lymphatic glands, general malaise, etc. The mortality rate in humans is not high, but thousands of rabbits die as a result of the infection. Some biologists are of the opinion that tularemia is a factor of great importance in "weeding out" the rabbit population when it becomes too numerous. Wild rabbits are therefore to be regarded as natural reservoirs of infection. Many other animal hosts, such as rats, field mice, sheep, muskrats, opossums, woodchucks, cats and game birds, are also recognized as reservoirs of infection.

The principal vector of tularemia seems to be the deer-fly (*Chrysops*). The wood-tick (*Dermacentor andersoni*), the rabbit tick (*Haemaphysalis leporis*

palustris) and the rabbit louse (*Haemodipsus ventricosus*) are also known to be carriers of infection.

While the deer-fly is one of the principal spreaders, the infective agent remains alive in its body for only a few days, whereas in the body of the wood-tick it remains alive throughout the life of this parasite.

Poultry raisers have also reason to fear ticks, because there are several species capable of causing considerable damage to chickens and other domestic fowls. For instance, the fowl-tick (*Argas miniatus*), commonly called the "blue bug," is such a pest in the southwestern states that poultry raisers have to wage a constant fight in order to keep it under control.

The fowl-tick, besides doing considerable damage to poultry by its blood-sucking propensities, also transmits fowl spirochetosis—a disease caused by a blood spirochete (*Spirocheta gallinarium*), first recognized in Brazil. It also affects poultry in other parts of South and Central America, Africa, Europe, and possibly in some of the southern states of North America. Spirochetosis is most common among chickens, but it is also found in geese, ducks, pigeons and sparrows. In Persia and Tunis the same disease is transmitted by a fowl-tick of the same genus as the above, namely, *Argus persicus*.

In addition to their blood-sucking habits and their ability to act as vectors of disease, ticks (at least some species) have a third undesirable quality—they are capable of causing a peculiar type of paralysis which is thought to be due to the injection of toxins into their victims at the time of feeding. Paralysis attributed to ticks has been reported in humans, dogs, horses, sheep, pigs, rabbits, foxes, moose and cattle. Definite proof that tick paralysis is caused by toxins secreted by the salivary glands of ticks and not by pathogenic organisms or virus is afforded by the fact that as soon as the ticks are removed from the body the patient makes a rapid recovery. So far as known, only female ticks cause paralysis. The tick chiefly responsible for paralysis in man and animals in the United States is the versatile wood-tick (*Dermacentor andersoni*). In Australia a dog-tick (*Ixodes holocyclus*) causes paralysis in dogs, poultry, pigs and other animals. There are no doubt a number of species of ticks capable of causing paralysis about which little or nothing is known at present.

While it has been generally accepted that tick paralysis is caused by a toxin secreted by ticks, the work of Wallace, Cahn and Thomas (1933) on "Moose Disease" is worthy of serious consideration. These investigators found that a disease of wild moose, resulting in paralysis of the limbs and usually in death, was apparently produced by a bacillus, *Klebsiella paralytica*. This organism was isolated from ticks (*Dermacentor albipictus*) that had fed on infected moose, and when cultures of it were injected into guinea pigs, rabbits, chickens, lambs and an Ayrshire bull, they produced symptoms which were practically identical with those seen in moose disease. It would therefore seem that the cause of tick paralysis is open to further investigation.

Acarina (mites): Several species of mites barely visible to the unaided eye burrow into the skin or other tissues of the bodies of domestic animals, causing considerable expense and exasperation to owners and being a source of great discomfort and ill health to their victims. The condition produced by mites is generally called mange by the laity and scabies by veterinarians. These names are derived from the fact that the burrowing habits of mites cause an outpouring of serum that coagulates or

dries on the surface of the skin, producing a thick, hard crust. In the case of scabies caused by sarcoptic, psoroptic and chorioptic mites, considerable irritation is produced which causes the affected animals to constantly rub themselves against convenient objects in order to allay the itching, thereby helping to spread the mites to other susceptible animals.

All these types of mange respond rather readily to appropriate treatment and proper sanitary regulations.

There is another species of mite, however, that is the despair of dog-owners and veterinarians alike. It is called the "follicular mite" (*Demodex folliculorum*). This mite invades the hair follicles and is very difficult to reach with parasiticides on account of its deep-seated and protected position at the base of the hair roots. So difficult is follicular mange to cure when well advanced that nothing short of heroic and persistent treatment can conquer it.

Another type of mange mite invades the ears of dogs, foxes, cats and rabbits, producing a scabby condition inside the ear which usually goes by the name of "canker"—a very inappropriate term, for canker may be due to other causes. The species of mites causing ear mange in dogs, cats and foxes is *Otodectes cynotis*. It causes a pronounced itching, so that the infested animals constantly scratch at their ears—which does not make matters any better. Bacterial complications may develop, with resulting inflammation of the middle ear, and possibly fits or convulsions and other disturbances which are very alarming to the owner and dangerous to the patient.

Another species of ear mite attacks the middle ear of domestic rabbits, namely, *Glyciphagus domesticus*. The condition produced by this mite is generally called "wry neck" by rabbit-breeders because the affected animals hold their heads on one side. In severe cases, rabbits are not able to stand up, and may die as a result of their inability to eat. This particular mite occurs only accidentally in the ears of rabbits. It is normally found in hay, straw and similar material.

In poultry there are several species of mites that cause serious pathological conditions; for instance, the common chicken mite (*Dermanyssus gallinae*) feeds on the blood of chickens during the night and hides in cracks and crevices during the day. This mite is one of the most serious pests the poultry raiser has to contend with. Quite recently another mite, *Liponyssus silviarum*, somewhat similar in morphology to the common chicken mite, has been introduced into the United States. This particular mite may become even more annoying to both chickens and their owners because it has entirely different habits. For instance, instead of feeding on the birds at night only, it remains on them all the time, even breeding among the feathers.

The scaly leg mite (*Cnemidocoptes mutans*) and the depluming mite (*Cnemidocoptes gallinae*) are two other mites which help to keep chickens entertained. The first produces a thick, scabby condition on the scaly portion of the legs, which is generally referred to by chicken raisers as scaly-leg. The depluming mite, as its name indicates, causes loss of feathers—the birds pulling out their feathers to ease the irritation produced by the mites. So badly denuded do some birds become that one might think they had started an avian nudist colony.

A discussion of mites would hardly be complete without reference to our old friend "the chigger" (*Trombicula irritans*), alias red bug, alias harvest mite, etc. Personally the writer does not

think the specific name of "irritans" is at all inappropriate; and he believes that any one who has been exposed to these pests will agree with him. Chiggers are one of the biggest curses of certain sections of the country, and one of the principal reasons why naturalists and other lovers of outdoors may, in spite of their enthusiasm, "quit the job" until the chigger season is over, unless they happen to have caught on to Dr. Ewing's prophylactic treatment in the form of liberal applications of sulfur to the lower parts of the body before going into chigger-infested territory.

Man is not the only animal attacked by chiggers; wild and domestic animals are seriously annoyed by them; in fact, chiggers often cause a high rate of mortality in young chickens continuously exposed to their attacks. Chiggers attack only in their larval form. The adults, according to Dr. Ewing, live largely on the fecal matter of arthropods and in decaying woody substances.

Chiggers in this country are not known to transmit disease, but the larvae of a Japanese species (*T. akamushi*) are responsible for the transmission of river-fever or "tsutsugamushi"—a highly fatal disease of man. The adults of this species of chigger live in the ears of field mice.

If the reader's patience has carried him to this point he will readily admit that insects and other arthropods are often of as much concern to the live-stock raiser as "overproduction" and failing markets for his product. It is rather strange that, while man has just about brought under subjection and control almost all the arthropods which cause him individual annoyance and sickness, he has done comparatively little to control or eradicate the legion of arthropod pests and vectors of disease which make the lives of domestic animals so miserable. As Dr. Maurice C. Hall has said, "man's chief concern seems to be to attack and destroy parasites which affect him personally," which perhaps accounts for the slowness with which he tackles the problem of controlling parasites of live stock. However, a tremendous amount of work has been done in the last few years in this direction, and it is the hope of the writer that this article may contribute, however slightly, to further interest in the control and eradication of the arthropod and other parasites of our benefactors and friends —the domestic animals.

THE EFFECT OF X-RAYS ON TISSUE REGENERATION

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EVER since the operator of one of the first x-ray tubes suffered the first x-ray burn it has been recognized that x-radiation is capable of exerting a profound effect on living tissue. Experimenters have found, however, that not all cells of an organism are equally sensitive to x-rays. Certain cells may be destroyed or may be rendered inactive by a dosage of x-rays which leaves other cells of the same organism apparently unharmed. It has been discovered that, in general, rapidly growing tissues are most susceptible to x-rays; tissues which are not undergoing rapid growth changes are less susceptible. This variability in the reaction of cells and tissues to x-rays places in the hands of the biologist an unusually efficient instrument of research, an instrument with which he is able to render certain cells inactive and by so doing discover the importance of these cells to the organism as a whole. X-rays, for example, have been found particularly useful in the investigation of certain problems of tissue growth such as the problem of regeneration.

Many animals possess the ability of regenerating parts of the body which have been lost through injury. In the case of the common earthworm, for example, if one end of the worm be cut off then the portion of the body which remains is able to regenerate the lost part in approximately its original condition. Lobsters and other crustaceans can regenerate new claws to replace lost ones, fishes can regenerate fins, and amphibians such as the salamanders are able to regenerate new limbs and tails.

About thirty years ago C. R. Bardeen and F. H. Baetjer discovered that the small flatworm, Planaria, which under ordinary circumstances regenerates lost parts of the body very rapidly, loses its capacity to regenerate after it has been exposed to x-rays. More recently it has been found, through studies by W. C. Curtis, that the failure of Planaria to regenerate after exposure to x-rays is due to the fact that the x-rays destroy certain cells in the body of the worm called formative cells. Since these formative cells normally are the source of the new tissue which is formed during regeneration, their destruction renders the Planaria incapable of regenerating. Much the same situation prevails in some of the segmented worms in which, as R. G. Stone has shown, specialized regeneration cells are destroyed by x-rays.

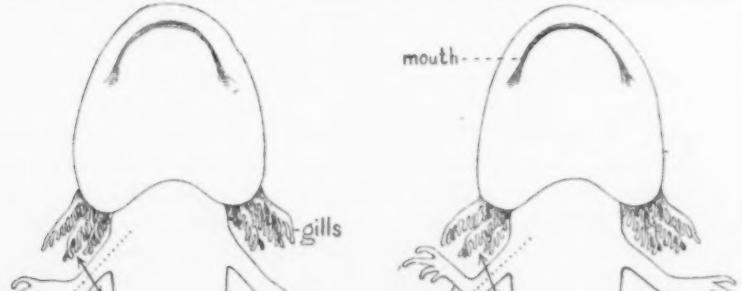
In the vertebrate animals no specialized regeneration cells, such as formative cells, have been found. However, a salamander which ordinarily can readily regenerate a lost limb, loses this ability after exposure to x-rays. This fact has been repeatedly demonstrated by experiments carried out in my laboratory in which the common American salamander (*Amblystoma punctatum*) was used. For experimental studies on regeneration the limb of this animal is a convenient structure, for the reason that under ordinary conditions it is very readily regenerated and in a young salamander regeneration of the limb takes place at a rapid rate. Within the space of three or four weeks, for example, a young salamander is able to regenerate an entirely new limb, the

length of time required depending to a large extent on the age of the animal. Younger salamanders regenerate more rapidly than older ones. However, if a salamander which possesses this remarkable capacity for regeneration be given a single exposure to x-rays in proper dosage, then this capacity is completely lost.

It has been found that the age of the animal used does not modify the effect of x-rays on limb regeneration. Regeneration is prevented as readily in an animal which possesses a fully developed limb as in a young larva in which the limb is just developing. The age of the animal or the stage of limb development, therefore, is not a factor. A salamander of any age when exposed to x-rays in proper dosage loses completely its ability to regenerate a new limb.

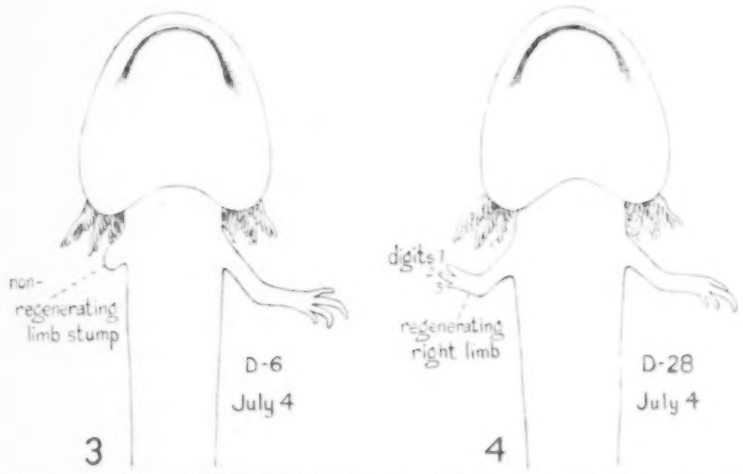
The description of a simple experiment will serve to demonstrate how readily observable are the effects of x-rays on regeneration. In Figs. 1 and 2 are represented in outline the fore part of the body of two young salamanders as seen from the under side. Each hand or fore foot has four digits, which is the full number of digits for the fore limb of this species of salamander. On June 12 the right fore limb of each salamander was amputated through the middle of the upper arm at a point indicated by the double pointed arrow. After the amputation the salamander shown in Fig. 1 was given a dosage of x-rays. The other salamander, shown in Fig. 2, was not x-rayed and was left to develop normally.

In Figs. 2 and 3 are represented the same two salamanders twenty-two days after the amputation of the right fore limbs. The x-rayed individual, represented in Fig. 3, shows a total absence of regeneration. The wound of amputation has healed, but no regeneration of a new limb has taken place. Fig. 4, representing the normal unradiated salamander, demonstrates the amount of regeneration which has taken place during the twenty-two day period. A new right



FIGS. 1 and 2. AMPUTATION OF THE LIMBS

THE DRAWINGS SHOW TWO YOUNG SALAMANDERS. THE DOUBLE POINTED ARROW ACROSS EACH RIGHT FORE LIMB INDICATES THE POINT AT WHICH THE LIMB WAS AMPUTATED ON JUNE 12. AFTER THE AMPUTATION THE SALAMANDER SHOWN IN FIG. 1 WAS EXPOSED TO X-RAYS. (THE DRAWINGS WERE MADE WITH THE ANIMALS LYING ON THEIR BACKS. IN EACH CASE ONLY THE FORE PART OF THE BODY IS SHOWN.)



FIGS. 3 and 4. REGENERATING AND NON-REGENERATING LIMBS

THE SAME SALAMANDERS SHOWN IN FIGS. 1 AND 2. THESE DRAWINGS WERE MADE 22 DAYS AFTER THE AMPUTATION OF THE RIGHT FORE LIMB OF EACH ANIMAL. NO REGENERATION HAS TAKEN PLACE IN THE X-RAYED SALAMANDER, FIG. 3. THE RIGHT FORE LIMB OF THE NORMAL UNRADIATED SALAMANDER, FIG. 4, IS REGENERATING NICELY.

limb has already regenerated as far as the three-digit condition. A few days after this drawing was made the fourth digit appeared, and soon the right limb was again in the same condition as the unharmed left limb.

In other experiments young salamander larvae in which the fore limb is just beginning to develop have been used. For example, one may amputate the limb bud at a time when it has just appeared on a young salamander larva as a small blunt protrusion or bud on the side of the body wall. Such an early stage of limb development is shown on the larva represented in side view in Fig. 5. Amputation at this early time consists simply in clipping off the free end of the little limb bud. The wound heals very quickly in a young larva, such as this, and, under normal conditions, regeneration of the limb bud and subsequent normal limb development takes place at a rapid rate. However, if after the amputation of the small limb bud the larva be exposed to x-rays, then the limb will fail to develop. This experiment shows that even in this young stage of development x-radiation has completely removed from the animal the capacity for limb regeneration.

Since x-radiation exerts so pronounced an effect on the regeneration of limbs, it is not surprising to discover that the normal development of limbs in young salamanders is also subject to modification by x-rays. Recently W. O. Puckett, working in the Princeton laboratory, has made a detailed study of the influence of x-rays on normal limb development. His work shows that exposure to x-rays at the proper time will completely suppress normal limb development. This effect may be readily demonstrated by the following simple experiment on hind limb development. Hind limbs in the salamanders used for these studies normally develop much later than fore limbs. It will be noticed in the salamander larva shown in Fig. 5, for example, that although fore limbs are starting to develop, there is no sign

of hind limbs. In fact, the fore limbs will be well along in development before the hind limbs put in their appearance. Now, if such a larva as shown in Fig. 5 be exposed to x-rays, then hind limbs will never appear at all. The salamander will develop into an individual which remains entirely limbless in the posterior part of the body.

Not only is it possible to suppress totally the development of limbs, but also one can suppress the development of parts of limbs. Consider, for example, the formation of the digits on the fore limb. Normally digits numbers 1 and 2 are the first to develop. They arise through the formation of two little outgrowths at the tip of the originally blunt limb bud. Then digit number 3 appears as a little outgrowth near the base of digit 2, as one sees it developing on the right limb of the animal in Fig. 4. Finally, at a still later time digit number 4 develops as a small outgrowth near the base of digit 3. In this manner the adult hand or fore foot is built up. Now, when one exposes to x-rays a young salamander larva with fore limbs on which only the first two digits have been formed, then the formation of the third and fourth digits will be prevented; each fore limb will remain as a permanent two-digit limb. Likewise, if one waits till a little later and radiates a salamander at a time when the first three digits have been formed, then the formation of the fourth digit will be suppressed, and the limb will remain

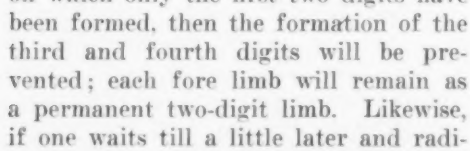


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FIG. 5. YOUNG SALAMANDER LARVA. (SIDE VIEW.)

THIS LARVA SHOWS AN EARLY STAGE IN THE DEVELOPMENT OF THE FORE LIMB, WHICH APPEARS AS A SMALL BUD GROWING OUT FROM THE SIDE OF THE BODY. THE HIND LIMB BUDS HAVE NOT YET APPEARED.

as a permanent three-digit limb. Moreover, as we have learned from earlier experiments, if at any time one of these permanent two-digit or three-digit limbs be amputated it will fail to regenerate. The exposure to x-rays which prevented digit development also removed the capacity for any future regeneration of the limb.

With these facts in mind, it will be seen that through the proper use of x-rays salamanders with almost any type of limb desired can be produced. For example, by radiating at a time when fore limbs have been formed, but hind limbs have not yet appeared, one can obtain an animal which possesses well-developed fore limbs, but no hind limbs at all. Also, by proper correlation of radiation and amputation it is possible to obtain a salamander, which, let us say, has one fore limb in a permanent two-digit condition and the other fore limb in a permanent three-digit condition. Indeed, by radiation at the proper time limbs with any desired combination of digits, within the limit of four, can be secured.

Thus far we have been considering experiments in which the entire salamander was subjected to the influence of the x-rays. Other experiments have been made in which a portion of the animal has been shielded with pieces of lead plates which are impervious to x-rays. By this method it is possible to subject only a certain definite part of the body to the x-rays. For example, by shielding the region of the hind limbs and radiating only the fore part of the body one renders the fore limbs incapable of regenerating, while the hind limbs retain their full potentialities. In this manner an animal which possesses hind limbs, but is without fore limbs, can be produced. Or, one may shield the right half of a salamander and leave the left half exposed to x-rays. Under these circumstances, both the fore and

hind limbs on the left side lose their capacity for regenerating, while the fore and hind limbs on the right side remain normal. These experiments demonstrate, among other things, that the effect of x-rays on limb regeneration is a local effect. In other words, it is an effect which the x-rays exert directly on the cells in the limb area, and is not a general effect on the animal as a whole.

Interesting as are the foregoing experiments, it is of still further interest and importance to inquire into the alterations which take place within the limbs of x-rayed salamanders. What changes have the x-rays brought about in the tissue, so that it is no longer capable of regenerating? In order better to understand the changes which take place within the non-regenerating limbs of x-rayed salamanders, let us examine first the manner in which new tissue is formed during normal regeneration of the salamander limb.

In Fig. 6 are shown three photographs of normally regenerating limbs eighteen hours, eight days and twelve days after the amputation of the limbs. Each photograph was made from a thin section which was cut lengthwise through the limb in the plane indicated by the dotted line along the right limb in Fig. 2. All three photographs are highly magnified. By a study of these sections one may follow the tissue changes taking place during regeneration.

The upper photograph in Fig. 6 shows a section through the stump of an amputated limb eighteen hours after the amputation. In the section are shown the scapula or shoulder blade and the humerus or bone of the upper arm which has been amputated about midway between the shoulder and the elbow. (In the young salamanders used for this experiment the humerus was made up of cartilage instead of bone, which develops later.) Healing of the wound of amputation has already taken place during the first eighteen hours. It consists, as shown in the photograph, in the growth over the raw stump of the surrounding skin or epidermis. During healing the epidermis becomes slightly thickened at the end of the limb, as the photograph shows.

The middle photograph in Fig. 6 shows the beginning of actual regeneration. Many alterations are now taking place among the cells of the limb stump which will result finally in the regeneration of a new limb. The first important change, and the one which is the signal for the building up of a new limb, is the appearance of a group of cells between the cut end of the humerus and the tip of the limb. These cells, well shown in the middle photograph in Fig. 6, make up what is known as the regeneration blastema. The cells of the blastema are of great importance, for it is from these cells that all the components of the new limb, except the nerves, will be formed. Once it has appeared, the regeneration blastema enlarges rapidly in size, and soon some of the cells of the blastema line up in rows preparatory to the formation of new cartilage at the cut end of the old cartilage stump. From then on regeneration of the limb goes on rapidly.

The lower photograph in Fig. 6 shows clearly the formation of new tissue, particularly cartilage, in a regenerating salamander limb twelve days after amputation. The new humerus is plainly mapped out as far down as the elbow. One can clearly see, however, where new cartilage joins on to the old cartilage. This point of junction indicates the place where the limb was amputated twelve days before. The formation of a new lower arm is also progressing rapidly. Already a little notch at the tip end of the limb indicates the formation of the first two digits. Soon the third digit and then the fourth will appear. Within a month after the original limb was amputated a new limb will have been completely regenerated.

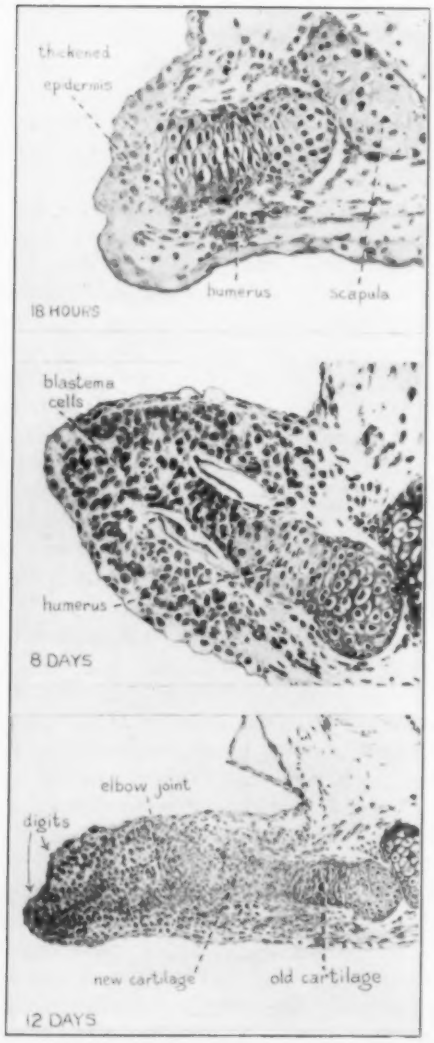


FIG. 6. REGENERATING LIMBS

THE PHOTOGRAPHS SHOW CHANGES WHICH TAKE PLACE WITHIN THE TISSUE OF THE SALAMANDER LIMB DURING NORMAL REGENERATION. EACH PHOTOGRAPH WAS MADE FROM A THIN SECTION CUT LENGTHWISE THROUGH THE LIMB IN THE PLANE INDICATED BY THE DOTTED LINE ALONG THE RIGHT LIMB IN FIG. 2. (ALL PHOTOGRAPHS ARE HIGHLY MAGNIFIED). THE UPPER PHOTOGRAPH SHOWS A LIMB STUMP 18 HOURS AFTER LIMB AMPUTATION. THE MIDDLE PHOTOGRAPH IS A REGENERATING LIMB 8 DAYS AFTER AMPUTATION. THE LOWER SHOWS REGENERATION PROGRESSING RAPIDLY 12 DAYS AFTER LIMB AMPUTATION.

Having in mind, now, the main tissue changes which take place during the normal course of regeneration, let us turn to a study of the conditions which one finds in the tissue of the non-regenerating limb stumps of x-rayed salamanders. What alterations in the tissue have the x-rays brought about which render the limb incapable of regenerating?

When one studies the changes taking place within the limb stump of an x-rayed salamander, such as the animal shown in Figs. 1 and 3, for example, one finds that they are strikingly different from those which accompany normal regeneration. However, differences in the tissue of radiated and unradiated animals do not become apparent immediately after amputation. During the first few days no very pronounced changes occur within the amputated limb other than the healing of the wound, which ordinarily takes place in an x-rayed salamander as rapidly as in a normal unradiated individual. On about the sixth day after amputation the similarity between the radiated and the unradiated animals ceases, and changes of an extraordinary and far-reaching nature begin within the limb stumps of the x-rayed salamanders. These changes are associated, first, with the region of the limb which normally is occupied by the cells of the new blastema, referred to above, and secondly, with the cartilage of the humerus.

In Fig. 7 are shown photographs of sections through the limb stumps of x-rayed salamanders six, eight and eighteen days after limb amputation. As before, these are photographs of thin sections cut lengthwise through the limbs in the plane indicated by the dotted line along the right limb in Fig. 1. A study of these sections reveals the differences between the tissue of non-regenerating limbs of x-rayed salamanders and the tissue found in normally regenerating limbs.

The upper photograph in Fig. 7 shows a section through a limb stump of an x-rayed salamander six days after the limb was amputated. One notices at once the absence of a regeneration blastema at the tip end of the limb, as was seen in normal regeneration. One observes, also, that the cartilage of the humerus is undergoing a striking change. These two are the most pronounced changes which are brought about by the x-rays. No regeneration blastema ever forms in the limb of an x-rayed salamander, and the old cartilage of the humerus, as time goes on, gradually degenerates and disappears.

The extent to which the cartilage dissolution or degeneration takes place in the limbs of radiated salamanders is startling. Eight days after the amputation all the humerus of the limb has dissolved and disappeared, except the upper end or head. Such a condition as this is shown in the middle photograph in Fig. 7. The dissimilarity between radiated salamanders and normal salamanders can readily be seen by comparing the middle photographs of Figs. 6 and 7. In the normal animal, Fig. 6, the rebuilding of the limb from the new regeneration blastema is just about to begin. In the radiated animal, Fig. 7, there is no regeneration blastema and no sign of rebuilding, but, on the contrary, an extensive degeneration of tissue has set in.

In the lower photograph in Fig. 7 is seen a non-regenerating limb stump of an x-rayed salamander eighteen days after the amputation of the limb. All tissues within the limb have now undergone degeneration. Not only has the humerus degenerated and disappeared entirely, but the scapula or shoulder blade is also gone. Such a limb as this can never regenerate, but will simply remain as a little stump on the side of the body. The capacity for regeneration has been entirely lost.

But is there no way at all, one may

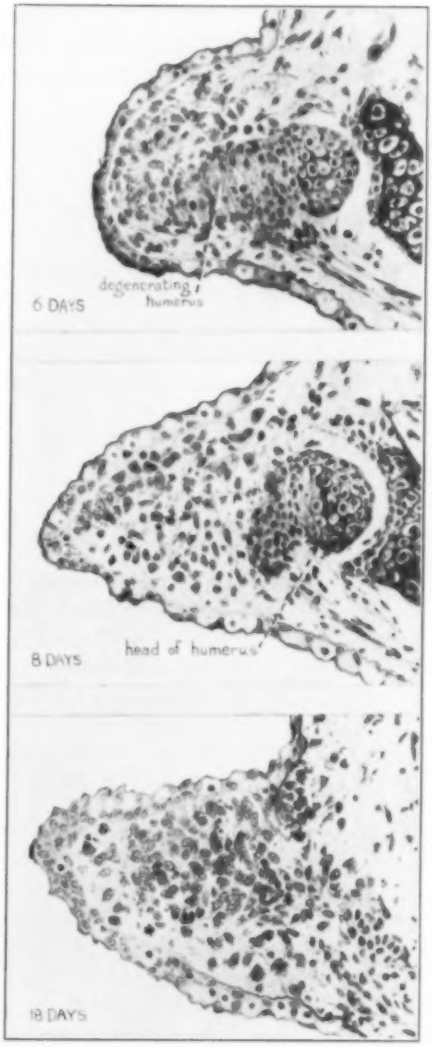


FIG. 7. NON-REGENERATING LIMBS

THE PHOTOGRAPHS SHOW CHANGES WITHIN THE TISSUE OF NON-REGENERATING LIMB STUMPS OF X-RAYED SALAMANDERS. COMPARE THESE SECTIONS WITH THOSE THROUGH REGENERATING LIMBS SHOWN IN FIG. 6. (THESE SECTIONS HAVE BEEN CUT IN THE SAME MANNER AS THOSE IN FIG. 6.) UPPER: NON-REGENERATING LIMB STUMP SIX DAYS AFTER LIMB AMPUTATION. MIDDLE: NON-REGENERATING LIMB EIGHT DAYS AFTER AMPUTATION. LOWER: DEGENERATION OF TISSUE IN A NON-REGENERATING LIMB STUMP EIGHTEEN DAYS AFTER LIMB AMPUTATION.

ask, by which an x-rayed salamander may regain the ability to regenerate a limb? Can not the animal in some manner be rehabilitated? The ability to regenerate can be restored only when a radiated animal is supplied with a new unradiated limb. This can be done by removing from a normal unradiated salamander a limb, and transplanting it to the body of an x-rayed individual. The transplanted limb may be placed in the normal limb location where it will grow, and often the salamander is able to use it in getting about nearly as well as it used its original limb. Now, if such a transplanted limb as this be amputated, then a new one will be regenerated. In this manner has the regenerative ability been restored to the x-rayed animal.

From a comparison, therefore, of the regenerative capacities of normal and x-rayed salamanders several conclusions are obvious. We find that when the formation of a new blastema is suppressed through the use of x-rays, then regeneration is prevented. We learn, moreover, that the cells which normally make up the regeneration blastema, and thereby enter into the formation of the new limb, come from the region of the limb itself and not from distant parts of the body, as some biologists have heretofore thought. The transplantation experiments just mentioned prove this point conclusively. We find, also, that in an x-rayed salamander the opposite of regeneration, namely, degeneration, takes place. It appears as though when tissues of the limb are prevented from regenerating, they must of necessity degenerate. There are reasons for thinking that the extensive degeneration of the humerus in x-rayed salamanders, for example, is due to the absence of a regeneration blastema.

Experiment, when applied to a study of developmental processes, invariably brings about the formation of abnormal animals. It is through a careful analysis of these abnormal individuals that the experimentalist gains new insight into the factors which underlie normal development. In x-rays the biologist has an efficient instrument of research, a new method for experimental analysis.

JOHN WESLEY POWELL
1834-1902[1]

By Dr. WILLIAM HERBERT HOBBS
PROFESSOR EMERITUS OF GEOLOGY, UNIVERSITY OF MICHIGAN

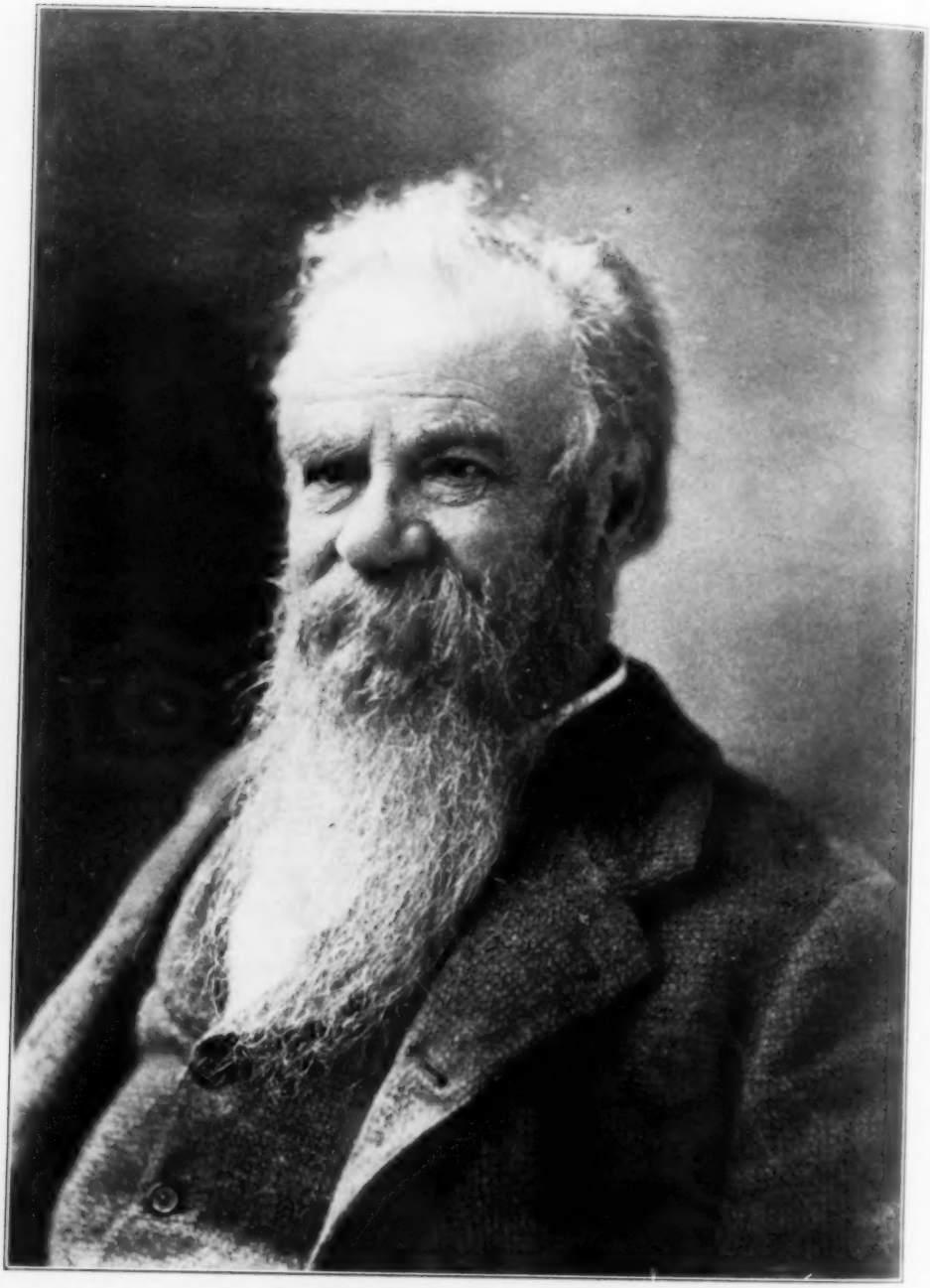
JOHN WESLEY POWELL'S many-sided career was an expression of that remarkable period which was opened by the American Civil War and followed by the development of the Great West. It was first as soldier, then as teacher, then explorer, later as geologist, anthropologist and philosopher; but perhaps more than all as the creative administrator who initiated and shaped the policies of some of our great scientific bureaus that his name will be long remembered. Powell was the father of the U. S. Geological Survey, of the Bureau of American Ethnology and of the vast Reclamation Service of the country. His life falls naturally into several distinct periods, each marked by a special line of endeavor.

John Wesley Powell was born on March 24, 1834, at Mount Morris in the State of New York. His father was a Methodist clergyman who had emigrated to America from England only a few years before. When Powell was seven years old his parents removed to Jackson, Ohio; five years later to South Grove in Walworth County, Wisconsin; five years later to Bonus Prairie, Boone County, in northern Illinois, and lastly to Wheaton, Illinois, where the Wesleyan College had just been established. During these peripatetic movements of the Methodist clergyman, the chief support of the family was a farm, which was left largely to the care of Powell as a mere boy, and he thus early learned the lesson of self-reliance and came into intimate communion with nature. Young Powell attended the country schools when he could, particularly at Janesville, Wisconsin, and later Wheaton and Illinois colleges irregularly, earning for a part of the time his support by service nights and mornings, by teaching and by lecturing on natural history. The only account of these lectures which has survived in print is one delivered at Ann Arbor, and for the reason that Powell was ragged by the students there because he wore a coat with long tails. His clever retort brought him instant applause. Later he had two years of work at Oberlin College, where he specialized in natural history. In 1859 he was elected to the secretaryship of the Illinois Natural History Society.

In the spring of 1860 Powell visited the southern states on a lecture tour and gained the clear impression that a civil war was inevitable. In the following summer he became principal of the public schools of Hennepin, Illinois, which with great vigor he organized and graded, keeping up, however, his natural history collections.

Powell's southern lecture tour had convinced him that a war between the sections was inevitable, and in the winter of 1860–1861 he took up seriously the study of military tactics and engineering. When Lincoln issued his call for troops, he was the first in his community to enlist, and Company H of the 20th Illinois Regiment of Volunteers was raised largely through his efforts, though he enlisted as a private and went out as sergeant-major. At Cape Girardeau, Missouri, his knowledge of military engineering made him invaluable, and he was

[1] The author is much indebted to Mr. Frederick S. Dellenbaugh, artist of Powell's second canyon voyage, who has read critically the manuscript and supplied illustrations.



—*Bachrach*

PORTRAIT OF MAJOR POWELL IN LATER LIFE.

given practical charge of constructing the fortifications of the place. As a consequence he was highly commended by General Fremont, and he was promoted to second lieutenant. When the regiment was ordered away, he was left in charge of the fortifications he had so largely constructed. In the winter of 1861–1862 he recruited a company of artillery from the loyal Missourians, which company became Battery F, 2nd Illinois Artillery, with Powell as captain.

Ordered to Pittsburg Landing, Tennessee, at the battle of Shiloh a rifle ball carried away his hand. Clumsily dressed, a second operation was unskilfully made in the hospital which left a small stump only below the elbow. Throughout almost his entire life Powell was never for any long period free from racking pains in this arm, and it was a few years only before his death that a third and elaborate operation at the Johns Hopkins Hospital gave him relief.

As soon as the earlier wounds were healed, despite his lost hand, Powell went back into service and at the siege of Vicksburg was a division chief of artillery. He took part in the operations at Natchez and New Orleans. In 1864 he was assigned to the army of Tennessee under General Thomas, bringing with him twenty batteries of artillery. He served on General Thomas's staff until mustered out at the end of the war.

In 1862 Captain Powell was married to his cousin, Emma Dean, of Detroit, to whom he had long been engaged. A few hours later with his bride he was on his way back to the field, where she took up the work of a nurse.

When in January, 1865, Powell was

—F. S. Dellenbaugh

POWELL'S MONUMENT IN ARLINGTON NATIONAL CEMETERY FINISHED IN 1914. POWELL'S FRIEND, COLONEL H. C. RIZER, IN THE BACKGROUND

discharged from the army after a career conspicuous for achievement, he dropped all interest in military affairs as suddenly as he had entered upon them. Though he had held high command with rank of lieutenant-colonel it was as "the Major" that he was always affectionately referred to in after life.

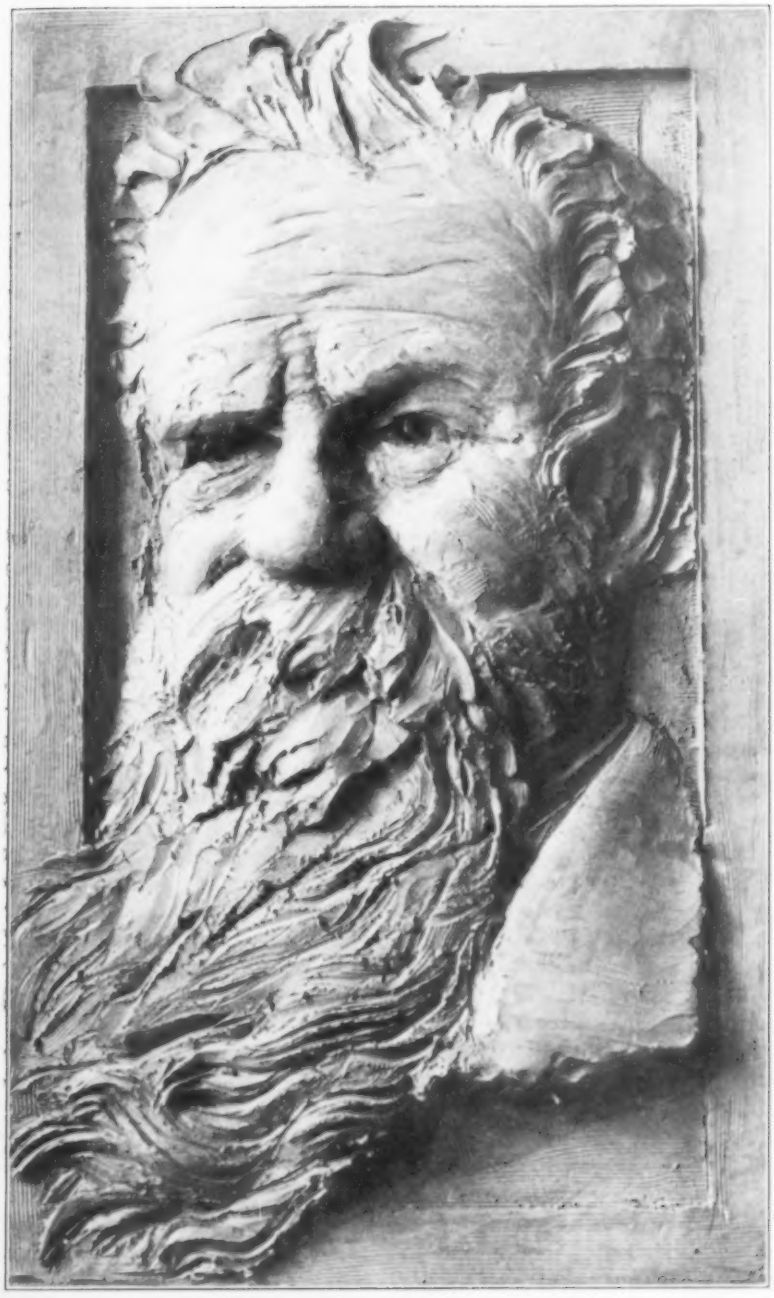
His career as a soldier concluded, Powell returned with great enthusiasm to his work as a naturalist and teacher. In 1865 he was made professor of geology and curator of the museum in Illinois Wesleyan University at Bloomington, but later he resigned to accept a similar position at Illinois Normal College. In 1867, with a class of sixteen students, he set out for the mountains of Colorado on what was the pioneer of extended geological field trips in America, and as that part of the country was not yet served by railroads, it was a somewhat arduous undertaking, but carried out with complete success. His faithful wife accompanied him on a similar trip in 1868 but with a larger party, and when the students returned, the Powells remained in the Rocky Mountains, wintering at White River in Wyoming, as he wished to continue his geological explorations.

This was the time that the idea to explore the Grand Canyon of the Colorado took firm hold upon him. Bold as this undertaking was, it was taken up in no spirit of adventure, but solely with a view to lift the veil from the scientific secrets hidden within the canyon's dark recesses. No one better than Powell appreciated the dangers to be faced. The Union Pacific Railroad had then just reached the crossing of the Green River in Wyoming. The Green was a tributary of the Colorado, and it was known that the waters fell 6,000 feet in the 1,000 miles before they reached the lowlands of the Southwest; and this to a certainty meant many rapids and falls. The country through which the river coursed was made up of high plateaus, within which the river was incised in steep-walled canyons from which it would in most places be exceedingly difficult, if not impossible, to climb out. Once launched upon the undertaking, there could be no turning back, and whatever the dangers, the only way to go was forward. After the winter spent in White River in Wyoming in careful exploratory work within the surrounding plateau country, Powell decided that, great as was the risk, the objects to be attained fully warranted the attempt to explore the canyons, and, as with Nansen, the results proved that his judgment was sound. Not a man was lost who remained with his leader.

In considering the audacity of this enterprise, it must not be forgotten that the leader had only the stump of his right arm, yet he always took his place as leader in the pioneer boat, and though repeatedly upset in swift rapids, with the aid of a life preserver he managed to make his way out by clinging with his one hand to the capsized boat. Many times the expedition missed complete disaster by the narrowest of margins, and once when about fifty miles from the end the rapids ahead were so terrifying and with no possibility of a portage that three members of the party refused to go on. These men succeeded in getting out of the canyon but were killed by the Shawits Indians on the plateau above. With his stauncher companions Powell succeeded in passing the first rapids safely, but all boats were swamped in a far worse falls farther down the canyon. However, they escaped safely, and shortly thereafter the boats ran out of the last of the granite into smooth water and the journey was at an end.

Powell has described this release from the canyon in some of the finest prose poetry in our language.

> The relief from danger and the joy of success are great. When he who has been chained by wounds to a hospital cot, . . . until the



RELIEF OF MAJOR POWELL ON WALL OF THE MUSEUMS BUILDING OF THE UNIVERSITY OF MICHIGAN, BY THE SCULPTOR CARLTON W. ANGELL OF ANN ARBOR

groans of those who lie about, tortured by probe and knife, are piled up, a weight of horror on his ears that he cannot throw off, cannot forget, . . . at last goes into the open field, what a world he sees! How beautiful the sky; how bright the sunshine; what "floods of delirious music" pour from the throats of birds; how sweet the fragrance of earth, and tree, and blossom! . . .

Something like this are the feelings we experience tonight. Ever before us has been an unknown danger, heavier than immediate peril. Every working hour passed in the Grand Canyon has been one of toil. We have watched with deep solicitude the steady disappearance of our scant supply of rations and from time to time have seen the river snatch a portion of the little left, while we were ahungered. . . . Only during the few hours of deep sleep, consequent on hard labor, has the roar of the waters been hushed. Now the danger is over; now the toil has ceased; now the gloom has disappeared; now the firmament is bounded only by the horizon; and what a vast expanse of constellations can be seen!

The river rolls by us in silent majesty; the quiet of the camp is sweet; our joy is almost ecstasy. We sit till long after midnight talking of the Grand Canyon, talking of home, but chiefly talking of the three men who left us. Are they wandering in those depths, unable to find a way out? Are they searching over the desert lands above for water? or are they nearing the settlements?

Owing to the defection of the three men it had been necessary to leave behind the geological specimens; and the hardships of the journey had made the traverse surveys uncertain and with important gaps. The leader was therefore unsatisfied with the results obtained and he determined to make another journey through the canyon. This time with government aid and a new party, a second canyon journey was carried out in 1871–1872 with many new perils, but now with complete success. Powell became a national hero, for the attention of the country had been focussed upon the expeditions and his first party had been reported lost. He thus became an earlier Lindbergh, and with equal modesty he shunned publicity. Nevertheless, in later years this position before the public was undoubtedly a great asset when it was necessary to secure appropriations from the Congress. Powell's interest, however, was wholly in the scientific results, and it was years before he published any narrative account, and then only when assured that he could expect no appropriations from Congress until his narrative was issued.

Powell's classic account of the Canyon journey is really a composite, a narrative of the first expedition with data inserted from the second. Nowhere would the reader suspect that the leader had lost an arm, though more than once he had been in serious trouble on this account, particularly when scaling the canyon walls for geological sections. Once when balanced precariously upon a narrow ledge high up on the canyon wall, he was forced to call for help. A companion higher up on the wall saw his predicament, but was without a rope. In desperation he divested himself of his underwear and lowered it from a shelf. Powell let go the rock just long enough to grasp with his one hand the improvised rope and was hauled to safety. Years afterward he wrote of his comrades on this expedition: "I was a maimed man; my right arm was gone; and these brave men, these good men, never forgot it. In every danger my safety was their first care, and in every working hour some kind service was rendered me and they transfigured my misfortune into a boon."

With the completion of the second Canyon journey, the second period of Powell's career, that of explorer, came to an end; and it is safe to say that no bolder expedition or one entered upon with higher motives or with more complete success has ever been undertaken in this country. In May, 1918, a memorial in the form of a stone altar supporting a bronze tablet with an account of Powell's expeditions was erected upon the brink of the Grand Canyon.

—*F. S. Dellenbaugh*

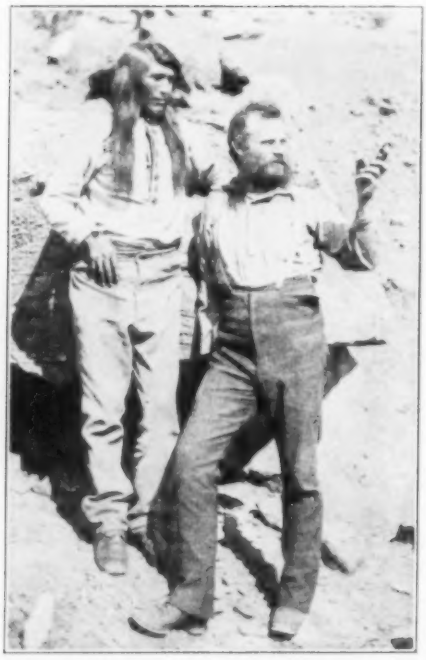
BRONZE TABLET ERECTED IN 1921

ON THE BRINK OF THE GRAND CANYON TO COMMEMORATE POWELL'S TWO VOYAGES. ON THE RIGHT IS F. S. DELLENBAUGH, ARTIST COMPANION OF POWELL ON HIS SECOND CANYON VOYAGE, AND ON THE LEFT EMERY KOLB WHO MADE A CANYON VOYAGE IN 1911. THE FLAG WAS CARRIED BY POWELL IN THE "EMMA DEAN" 1871–72.

Powell's studies within and about the Grand Canyon and within the Rocky Mountain Region continued for nine years and were made along three different lines—in geology, anthropology and reclamation, in each of which Powell was destined to become a foremost authority. The geological results of his labor are published in two quarto monographs as government publications, and in many shorter papers. The area covered is probably unsurpassed for the display on a large scale of geological structures, and the keen mind of Powell enabled him to lay the foundations of wholly new chapters in geological science. A new subscience of geomorphology or physiographical geology was born of his studies.

To cite Gilbert: "In connection with the field studies in these districts he developed a new classification of mountains, by structure and genesis; a structural classification of valleys; and a genetic classification of drainage systems. His classification of drainage recognized three modes of genesis, of which two were new. With the novel ideas involved in the terms 'superimposed drainage' and 'antecedent drainage' were associated the broader idea that the physical history of the region might be read in part from a study of its drainage system in relation to its rock structure." Another idea of the utmost importance to the science, that of "base level of erosion," we owe to these studies of Powell. Outside these greater monographs Powell published many shorter articles, and his complete bibliography includes 251 items.

As director of the Geographical and Geological Survey of the Rocky Mountain Region, Powell was authorized to engage other geologists, and he brought to his survey G. K. Gilbert and C. E. Dutton, whose monographs on the Henry Mountains and on the High



—F. S. Dellenbaugh

MAJOR POWELL WITH CHIEF OF THE PAI UTES IN THE COLORADO REGION IN THE EIGHTEEN SEVENTIES.

Plateaus of Utah later published by his survey are to-day among the great classics of the science. Gilbert became one of the very greatest of American geologists, and he has borne testimony to Powell's contribution of ideas to his colleagues.

> Gathering about him [writes Gilbert] the ablest men he could secure, he was always their intellectual leader, and few of his colleagues could withstand the influence of his master mind. Phenomenally fertile in ideas, he was absolutely free in their communication, with the result that many of his suggestions—a number which never can be known—were unconsciously appropriated by his associates and incorporated in their published results. I have elsewhere expressed the opinion that the scientific product which he directly and indirectly inspired may equal or even exceed that which stands in his own name.

Powell's studies of the Indian races began simultaneously with those on the geology of the West and were continued at every possible opportunity. We owe to him important pioneer studies, especially on the Indian languages, Indian handiwork, customs, mythology and philosophy, with their origin and tribal relationships. According to McGee the principle of genesis was the keynote of Powell's researches in ethnology and in general anthropology:

> He mastered the Indian languages, first as a means of gathering facts and later for their own inherent interest. . . .
>
> The published details of Powell's work fill volumes; yet in ethnology and general anthropology, no less than in geology, the larger share of the fruit of his vigorous thinking was turned over freely to colaborers, with a generosity unparalleled in the history of Science, to find its way into the general body of human knowledge under other names than his own.

But the period of Powell's life spent primarily as a research scientist was soon to be replaced by that of the administrator, and from now on until his retirement in 1894, his time and thought were to be devoted largely to the direction of great government bureaus. Almost simultaneously with the organization of his first survey department in the West, there had grown up three other organizations generally known respectively as the Hayden Survey, organized under the General Land Office, the King Survey, under control of the Army engineers, and the Wheeler Survey, also under the Army. The Powell Survey was organized under the Smithsonian Institution but was later transferred to the Interior Department. There was lack of coordination and an overlapping of work with consequent waste of public funds, and quite naturally each director was ambitious for his own organization and was in competition with the others to secure public support. As early as 1875 the need of combination under a single head had become apparent, and in 1879 Congress referred the matter to the National Academy of Sciences for rec-

ommendation. A distinguished committee was appointed from the academy, but it was largely through Powell's advice and initiative that the four surveys were in 1879 merged in a new organization administered under the Interior Department and known as the U. S. Geographical and Geological Survey. Because of the important rôle that he had played in securing this result Powell declined to have his name considered for head of the new organization, and Clarence King was by Presidential appointment made the first director. At the same time the Bureau of American Ethnology was created under the Smithsonian Institution to take over the ethnologic work of the several surveys, and Powell was at once made its director. After a little more than a year King resigned from the Geological Survey, as it was later called, and Powell was immediately named his successor. He thereafter served as director of both bureaus until 1894. It was under him that the Geological Survey grew and its policies were largely shaped.

> There are administrators [says Charles D. Walcott] who achieve a fair amount of success through securing from the organization economical and efficient work along prescribed lines. These are, properly speaking, executives. There are administrators of another kind, who possess insight and creative ability, who have scientific imagination and the power of initiative. Their conceptions are broad and clear; they are not only masterful in execution, but fertile in suggestion and potent with the authorizing power. Among this class Major Powell was eminent.

From the start Powell elected to attack the larger problems of pure science and if the practical investigation of a mining district was to be made, those problems involved which were of a purely scientific nature were not overlooked. As one now surveys the noble series of monographs and of annual reports issued by the Survey and by the Bureau of Ethnology during Powell's term of office, he can not but be impressed with the large proportion which have become classics of the science. In no equal period since that time has any comparable set of publications been issued by the Survey. His was the most glorious period of the U. S. Geological Survey.

When in 1867 Powell made his first visit to the Great West, his keen mind grasped the future possibilities of this vast semi-arid region through irrigation, and from that time the subject was never laid down but became one of the major efforts of his busy life. In 1878 he brought out his monographic report on the "Lands of the Arid Regions of the United States," which was soon issued in a second edition. In this monograph he set forth with marvelous insight the essential conditions for irrigation, a formulation of the principles by which much of the later work was guided. As director of the Geological Survey, he soon enlarged its scope to include the investigations of water supply with special reference to irrigation. The flow of streams was measured, reservoir sites were surveyed and extensive researches were carried out upon the conservation of water supply. He thus trained the fine body of men who became known as "his boys"—the sons of the Reclamation Service as he was its father. No one better than Powell knew the irrigation possibilities, and he was determined that this great heritage should be vested in the people themselves so that they should never be robbed of their rights through the operations of water companies. Powell early saw that only the Federal Government could undertake such gigantic projects, which would require expenditures in the aggregate of billions of dollars. "The world owes the gift," says the historian of the Service, "to John Wesley Powell, the father of the Reclamation Service."

It was but natural that powerful private interests should be arrayed in opposition to Major Powell. At first he was

discredited because he boldly announced that only a small percentage of the West could ever be reclaimed, and he declared to be semi-arid the middle plains belt where the railroads were then luring settlers to their undoing. He pointed out clearly the evils which must be remedied through legislation.

The attacks upon Powell were aimed directly at the Geological Survey, and in 1892 his enemies in Congress delivered upon it a body blow which left it crippled to recover only slowly. During a luncheon recess of the Congress these men succeeded in bringing together a bare quorum and the Survey appropriation was reduced by almost one third. The day is well remembered by the writer, who received from the director a laconic telegram to stop field work at once, and similar telegrams went to field parties throughout the country. Not long thereafter under his successor the policy was inaugurated in the Survey of undertaking those studies only which could be seen to lead directly to a "practical" solution which could be measured in terms of dollars.

Two years later in failing health, Powell resigned his position as director of the Geological Survey, delegated the direction of the Ethnological Bureau, and the labors for a proper Reclamation Service had to be taken over by others, but mainly by the men he had developed. The bill which founded the great Reclamation Service was finally passed in 1902 with the powerful support of President Theodore Roosevelt. Powell, seriously ill and only three months before his death, was greatly cheered by the news of its passage.

Powell's interest in philosophy had been early stimulated by his study of the primitive philosophy of the Indian tribes, and with his retirement from administrative responsibilities, he turned to studies of psychology and philosophy, which took up his attention during the last eight years of his life. Four years before his death he published "Truth and Error, or the Science of Intellection," a book of over four hundred pages in which his philosophy is clearly set forth. In reading it one is constantly reminded of Huxley by its trenchant phrases as he hews to the line through some of the unrealities of metaphysics. I shall content myself by references to the opening and the closing pages of "Truth and Error," which in some measure indicate its trend.

Powell relates that once on the brink of the Grand Canyon he was in camp with Indians, and with their chief, Chuar, they amused themselves by throwing stones out over the canyon in a vain attempt to reach the other wall. Chuar expressed the belief that he could throw a stone much farther over the plateau than he could over the canyon, and he explained that the canyon pulled the stone down. He thus reified void and imputed to it the force of a pull.

> Now [says Powell], in the language of Chuar's people, a wise man is said to be a traveller . . . as they suppose that a man must learn by journeying much. So . . . I told Chuar that he was a great traveller, and that I knew of two other great travellers . . . one by the name of Hegel, and another by the name of Spencer, and that I should ever remember these three wise men, who spoke like words of wisdom, for it passed through my mind that all three of these philosophers had reified void and founded a philosophy thereon.

The sentences which conclude the volume are: "The war of philosophy is between Idealists and Materialists. The philosophy here presented is neither Idealism nor Materialism. I would fain call it the Philosophy of Science."

A second volume entitled "Good and Evil" appeared in serial form as separate essays, but was never brought out in book form, and a third volume, planned to treat of the emotions, was never completed. As a philosopher Powell was but little known, but his

vigor of thought and clarity of expression merit a wider consideration.

In later life honors poured in upon Powell. He was elected to the National Academy of Sciences, the American Philosophical Society and the American Academy of Arts and Sciences. Harvard University and the Columbian University, as well as many other institutions, conferred upon him their honorary degrees of doctor of laws, and the University of Heidelberg in Germany made him an honorary doctor of philosophy. He was elected to the presidency of the Geological Society of America and the American Association for the Advancement of Science. He was president of the Anthropological Society of Washington from its foundation in 1879 until 1888. In 1891 the French Academy of Sciences awarded him the much coveted Cuvier Prize.

In personal appearance Powell was a notably rugged type, a hairy man with large bulbous nose, a patriarchal beard, and with rather small eyes under bushy eyebrows. In later life his face was deeply seamed, which might tell something of what he had suffered from torturing pain. His figure was that of a sturdy oak, gnarled and seamed and with severed limb, which had withstood the blasts of many winters. The face was not a handsome one, but it was one which could not be overlooked in any assembly.

As a man Powell was in high degree self-contained, and his intimate friends were in consequence a small company only, though he drew a host of others to admire and love him. Referring to his associates on the occasion of his retirement from the Geological Survey, his valedictory statement is full of pathos:

> In this severance of our relations [he wrote], made necessary by painful disability, I cannot refrain from an expression of profound gratitude for the loyal and loving aid which they have given me, ever working together with zeal and wisdom to add to the sum of human knowledge. The roster of these honored men is found in ten-score volumes of contributions to knowledge and fifty-score maps familiar to the scholars of the world, and their names need no repetition here. . . .
>
> With feelings of deep endearment I say goodbye.

He died at his country home at Haven, Maine, on September 23, 1902, in his sixty-ninth year. One of his closest friends, Dr. S. P. Langley, then the distinguished head of the Smithsonian Institution, has written feelingly of him:

> If there be anything outside the soldier, the explorer, or the man of science, it lay in a singularly simple and strong humanity; a something which took hold of you and made you his friend. While he was here he filled an almost unique place in one's life, and now that he is gone there remains a gap which no other can fill. . . . He was a Stoic who suffered long years of pain in silence and who at the end met the approach of death as though it were a familiar incident of life. . . . We shall not often look upon his like.

IS A SCIENCE OF EDUCATION POSSIBLE?

By Professor FREDERICK S. BREED
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DURING the present exciting field day for critics of our commercial and industrial system, our banking and education, our morals and religion, our liberalism and democracy—our social institutions in general, each must determine for himself the value of an answer to a destructive assault. The formula for the fame of the headlines is simple enough and widely diffused: crack down a public idol with iconoclastic zeal or kidnap him. On occasion one discerns a glint of wisdom in the weathered old Canadian settler who, when he received a bill for taxes in figures of disturbing magnitude, was never at a loss to know how to dispose of it. Documents of this description were summarily devoted to the primordial derisive use of such impertinences.

An article which recently appeared in *Harper's Magazine* under the title, "Educators Groping for the Stars," should be spared the cruel fate of insult added to the injury of neglect, and for two reasons. First, though negatively vigorous, it is constructively negligible. Second, it is not even dependable in its vigorous negation. It brings to mind the penchant for misinformation and distortion exhibited by a young lady described by Stratton Brooks when he was superintendent of the Boston public schools. "She was a splendid teacher," he said, "of things that aren't so." In their enthusiasm for scientific research, the author, Mr. Nathaniel Peffer, charmingly likens educators of the present to the legendary general who at the first sound of alarm flung himself into the saddle and rode off in all directions at once. Peffer, of Guggenheim affiliation, bears a closer resemblance to our own General Hooker, who shortly after his appointment to the command of the Army of the Potomac, is reported to have sent a message to President Lincoln embellished at the top—"Headquarters in the Saddle." Lincoln read the message, then drily remarked: "There is only one trouble with Hooker. His headquarters are where his hindquarters ought to be."

A careful analysis of the article soon throws the causes of irritation into bold relief. Educators are suffering from a species of "frenetic inflation," "grandiloquent fancies," "wild divagations" and the excessive "altitude of their ambition."

"I beg your stuff?" says Baron Munchausen.

Well, a less rhapsodical diagnosis of the malady shows it to be threefold. It consists of the misguided adoption of the following aims: (1) Reconstruction of the social order, (2) integration of individual personality, (3) scientific investigation of educational problems.

A coterie of educators has been discovered whose central objective is the reconstruction of the social order. These educators have been greatly impressed by the bolshevist movement for social reform in Russia. They favor national planning and a collectivistic state. They would even enlist the energies of the schools in subversive activity for the accomplishment of their revolutionary ends.

As a judge in Pittsburgh recently remarked, "These fellows are not educators; they should hire a hall and go into politics." Too true. They represent neither the educational sentiment of the nation nor the views of the vast

majority of intelligent leaders. They represent the radical fringe. Moreover, they have undertaken a task of leadership that calls for competent specialists in the social sciences, when there is not a sociologist or economist or political scientist of recognized scholarly standing among them. It is obvious, then, that I have no quarrel with one who disputes the ambitious claim of these revolutionary agitators in pedagogical clothing. I even admit that a genuine service has been performed by turning a searchlight on the weaknesses of their position. I simply resent the implication that this type of radicalism has seriously infected, much less permeated, the real educational leadership of the nation.

Nor do I object to the outburst against those who worship at the mystic shrine of "integration." When vaguer educational aims are made, such people will make them. But after a valiant effort to relieve education of irrelevancy and mistiness, of social reconstruction and individual integration as basic purposes, Mr. Peffer, with curious inconsistency, ends his discussion by lifting John Dewey to a lofty pedestal and bowing down in worshipful regard to him as one "who has been our greatest pioneer in educational thought." This in the face of the fact that both of the doctrines so bitterly attacked have been absorbed in the program of the self-styled progressive school in education, of which Dewey is high priest and acknowledged leader. The doctrines, social reconstruction and individual integration, are not horrible examples of "a superficial rendering of John Dewey's educational philosophy." They bear the stamp of his approval in authentic documents. He is the open champion of both.

The third distressing feature of modern educational policy, we are informed, is the adoption of the scientific method. This policy is judged the ill-starred child of much beclouded brains. And what a comedy of errors it seems to entail. "All that education has taken over from science," our critic contends, "is the word research. By its very nature that is all it can take, for it deals with too many factors which are imponderable, which by their very essence are not measurable by fixed and unchanging standards."

The picture which is painted of the attempts of educators to apply scientific methods in the investigation of their problems is a product of the misinformation and distortion earlier referred to. The outmoded questionnaire, precarious tests of character traits and rating scales for measuring qualities of personality are held up as representative of techniques regarded by educators as scientific, when the truth is that the questionnaire method, except as a legitimate index of mere opinion, is in thorough disrepute among educational investigators; the problem of measuring such character traits as loyalty and leadership is known by them to be unsolved; and the rating scales employed on occasion by superintendents of schools in estimating the degree of certain desirable personal traits possessed by teachers have been shown by educational experimentalists themselves to be highly unreliable because highly subjective.

Now let us bend a little nearer to our task. Is there any possibility of a science of education? If there is, it will not be discovered by negative dogmatists. Nor will the possibility of such a science be demonstrated by abortive examples, like those cited above. But even on these examples one can look with a measure of tolerance if one stops to reflect that not every pedagogue who mails a questionnaire is entitled to represent the scientific personnel of his profession, that in many fields the desired objectivity of method is achieved only after repeated failure, and that the possibility of a science of education

must be judged by the best and not by the worst of its investigations.

It is a commonplace to remark that science and measurement develop hand in hand. As methods of measuring are devised, science advances. This has been notably true in physics, which has been taken as the pattern for all exact science. The laws of physics are based on facts determined by measurement—facts regarding the mass, volume, temperature, velocity, and the like, of objects. Such terms as these denote either qualities or relations between qualities. Temperature is a quality of an object. Velocity is the ratio between a spatial and a temporal quality.

$$V\ (\text{velocity}) = \frac{d\ (\text{distance})}{t\ (\text{time})}.$$

That is, if I divide the distance you run by the number of minutes you run, I have your rate, or velocity, of movement. If v remains constant while both d and t change, we have an example of the type of uniformity that science discovers in the midst of change.

Now let us revert to our qualities for a moment. We spoke of the qualities of an object, but on reflection it becomes evident that an object of perception is a combination of qualities. By measuring the qualities one measures the object. Moreover, one measures the qualities in *amount*. Length is a quality of an object and is measured in amount by an instrument known as a yardstick. Temperature is a quality and is measured in amount by an instrument known as a thermometer. Every quality seems to come in some amount. It possesses either extensive or intensive magnitude, each of which is measurable with more or less exactitude. It should be observed, further, that the measurement is always in terms of arbitrary units on a scale. As Eddington has said, measurement always resembles the action of a pointer on a dial. Indeed, a quality in last analysis becomes to science an event coordinated with another event. Measurement expresses a relation between events. Something happens and the pointer registers something. That is measurement. And, finally, the measurement never has the perfection of accuracy so commonly supposed. Every measurement is a statistical approximation.

In the interest of clearness it may be well to dwell a moment longer on the last preceding point, for many persons no doubt still believe that scientists, especially physical scientists, can measure with greater precision than was just indicated. The difficulties in the way of perfect measurement can be illustrated, however, by a very simple example. Suppose I bring forth a yardstick and ask each of a group of scientists to measure the length of my desk to the nearest inch. When the results are announced I would expect no variation among them, unless perchance one of my guests became so bored by the triviality of the task that he absent-mindedly forgot the assignment. We shall endeavor to awake even his interest by next asking for a measurement to one thousandth of an inch. Now the difficulties begin to pile up so fast that we shall not have time to enumerate them. Immediately I hear a demand for a more accurate instrument of measurement, a demand for specification of the point on the side of the desk from which the measurement is to be made, and the like. I insist, however, on the original problem—measuring the length of the desk with the yardstick, and this time I shall be surprised if any two measurements agree. Even if the task be made more specific and a finer instrument be supplied, all I need to do to prove my point is to reduce the size of the unit on which I demand agreement. A light-year is the yardstick of celestial measurement, yet no astronomer knows precisely the velocity of light. Atomic weights are

basic units in chemical analysis, yet no chemist knows the precise value of a single one.

When, now, one turns from the field of physical measurement to that of mental measurement, the fundamental principles are found to be the same. Early skepticism in regard to the possibility of mental measurement probably grew out of the belief that it is ridiculous to think of laying a yardstick on an individual's stream of consciousness or on his psychic states. It *is* ridiculous. Modern educational and psychological investigators have no such preposterous purpose as measuring states in the stream of consciousness. Many of them have even discarded the notion of a subcutaneous mind—whether in the form of a soul in the pineal gland or of sensory ghosts in the brain cells.

The chief function of all education is direction of the learning process. Learning therefore becomes the first topic of interest to educators. Can learning be measured? Certainly. It is something that is directly observable and can be measured as simply as the reactions of people can be measured, for it is a *change* in reaction, a modification of the behavior of an individual. The real test of learning is the acquisition of a selective reaction to an object or stimulus. One merely presents a stimulus to a pupil and notes whether or not the desired specific reaction is made. This is the methodology of modern educational tests and can be illustrated by the following items clipped from a standard test on knowledge of literature:

75 "Lead, Kindly Light" was written by
Carlyle **Cardinal Newman** **Phillips Brooks**
76 "Captains Courageous" is about
Ben Gunn **Diska Troop** **John Silver**
77 "Flow Gently, Sweet Afton" was written by
Burns **Keats** **Tennyson**
78 "The Ancient Mariner" was written by
Browning **Coleridge** **Longfellow**
79 "Annabel Lee" was written by
Poe **Longfellow** **Wordsworth**

The test item in each case is the stimulus, to which the pupil reacts selectively by underlining the name of the author or character that makes the sentence true. The stimulus may be a real object, but it is usually a verbal substitute therefor. By this technique there would be no special difficulty in measuring the degree of acquaintance of the reader with authors and characters or in finding out how much he has learned regarding them during a given period. In the latter case two tests of equal difficulty covering the field and separated by the desired interval are used. These are called duplicate tests.

The technique of educational and psychological measurement is objective enough to satisfy the most rigorous demands of the most ardent behaviorist. The modern tester may not deny that psychic states exist, but so far as he is concerned they might well be non-existent, for he has no commerce with them. A standard educational or psychological test is nothing more than a series of stimuli. The stimuli are objective in the strictest sense—their existence is verifiable by another observer. The pupil's reactions to the stimuli are objectively recorded. Usually they are recorded in pencil by the pupil himself on a test sheet. His score on the test is simply a summarization of the reactions.

Tests of this character measure directly, then, the objectively observable reactions of pupils. More specifically they measure qualities of reactions. The qualities most commonly measured are accuracy and rate. Standardized tests are now available for the measurement of accuracy and rate of reaction in many areas of instruction, including reading and handwriting, spelling and computation, vocabulary development and problem solving. Accuracy and rate, like any other qualities, are measured in amount. If a pupil responds correctly to 75 out of 80 items in the word-meaning section of the New Stanford

Achievement Test, his percentage of accuracy is clearly 94. His rate is measured by a stop-watch.

In this manner many types of mental content and activity can be measured. When and if all types are measured, mind will be measured, for, so far as we know, a mind and its activity are nothing more than a manifold of terms in certain relationships. We can discover what one knows about banking or foreign exchange, Latin or the tariff, and we can discover how accurately one can put two and two together in these fields. All that is necessary is the presentation of a sufficiently large number of representative problems and items of information. This is a matter of random sampling, as is all such testing. From the significant material in the field one selects items in sufficient number to yield an accuracy score approximately equal to that which would have been obtained if all the items in the field had been presented.

For the success of this plan it is obvious that two things are needful: First, knowledge of the most important content in the field in which the testing is to be done and, second, the proper sampling of the content. Few people outside the teaching profession are aware of the vast amount of detailed objective work that has been done to discover the important materials in various subjects of study. Take spelling, for example. Consider first that the demand for spelling arises in life when one is attempting to express one's thought in written form. The central aim in the teaching of spelling, therefore, is to enable the individual to write correctly the words that are needed in his written discourse. Can these words be discovered? They have been discovered. They have been discovered by tabulating all the different words found in the written work of thousands of children and adults. Millions of running words have been thus tabulated from the themes and letters of children, and from the business and friendship letters of adults, with the frequency of occurrence of each word. The results have been nothing short of a godsend to the millions of boys and girls in the public schools, for whereas pupils were formerly required to learn the spelling of as many as 12,000 to 15,000 different words, to-day, where schools are scientifically organized, the number of words in the elementary grades has been reduced to about 4,000. The reduction was made possible because it was found that if one learns to spell no more than the 500 words of highest frequency in the 4,000, he will be able to spell 82 per cent. of all the running words used by ordinary adults, and if he learns to spell the whole 4,000, he will be able to spell correctly nearly 99 per cent. Within the range of a reasonably small probable error, the words that children should be taught to spell are known. And with this first problem solved, the second requirement becomes nothing more than a mechanical procedure. The only serious question relates to the size of the random sample, and statistical studies show that for a sufficiently reliable measurement of an individual pupil on a year's work in spelling, a test containing at least 50 words is necessary.

Now a word in regard to accuracy of measurement. This is an extremely important question, for it has even led some of our educators to abandon hope and exhibit all the earmarks of an inferiority complex. Such self-abasement might be more unbecoming in a drum major, but it would not be more unnecessary. In education and psychology we not only measure quantitatively the quality of objectively observable events, but like the physical scientist and by the same method we determine the reliability of the measurements. This is done by the computation of the probable error of measurement, a relatively simple

statistical process well known to workers in science.

For the best tests in school subjects the probable error of a pupil's score from a single competent measurement has been reduced to 2 points on a 100-point scale. This error is still very large in comparison with the probable error of physical measurements, but its size is no reflection on educators. Greater accuracy of measurement is in general possible in physical than in biological or psychological science, primarily because of difference in material measured. There are two outstanding conditions that interfere with accuracy of measurement—variability of the matter and variability of the manner, and in mental measurement the first is the worst offender. A block of material on the frame of a ten-story building has a remarkable consistency of behavior compared with the block on the frame of a ten-year- old boy. The size of the probable error is due much less to the wobbling of the tester than to the wobbling of the testee. In any case a measurement must always be as wobbly as that which is measured. Now if a boy obtains a score of 67, with a probable error of 2, just how variable is such a score? A score of 67 ± 2 means that if he were measured an indefinitely large number of times by competent testers, half of the scores would be between $67-2$ and $67+2$, or between 65 and 69. In other words, there is a fifty-fifty chance that the boy's true score will not vary from 67 more than 2 points either way. This degree of accuracy in educational measurement has become possible only since 1910, when the conception of the standardized educational test and the method of constructing an educational scale were made known.

Educational measurement is still in its early infancy. A quarter of a century is but a day in the life of such a development. Yet in spite of its youth it already has a clear grasp of the principles underlying its program and faces its future as well as its critics without apology for its existence.

Educators can be classified into three fairly well-defined groups: (1) the traditional, (2) the scientific and (3) the philosophical. This is a conservative-liberal classification and is made in terms of the most important dimension of social leadership and social institutions. The traditional group represents extreme conservatism and is primarily interested in the preservation of the *status quo*. The scientific group is conservatively progressive, and the philosophical group, known more commonly as the "progressive" school, harbors the radicals of the profession. Our critic castigates the radical and scientific groups, then fervently prays for an educational holiday. "I suggest," he says, "that educators take themselves at whatever point they now find themselves, resolving only to do well that which they are now doing." Thus he turns to rugged traditionalism as a means, one surmises, of placing education on a Guggenheim foundation. Why not try to put it on a scientific foundation? This would solve the problem for one who desires to escape the stagnation of traditionalism on the one hand and the uncertainties of radicalism on the other. For such a one the educational slogan would be, As progressive as science.

A SCIENTIFIC APPROACH TO EMOTIONAL PROBLEMS

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IT is alleged that one of those dubbed "brain trusters" has asked what part of the body can be trusted better than the brain. The difficulty is that some of those in the saddles at Washington tend to trust the heart rather than the brain. To a professional psychologist, who is an amateur economist, it seems that the President is a better practical psychologist than he, a more amateur economist. A scientific approach to the emotional side of economic problems is not easy.

Laplace, the great French mathematician, proposed an equation to the effect that the *fortune morale* is equal to the logarithm of the *fortune physique*. A corresponding psychological formula was later developed by Weber and Fechner, stating that the intensity of sensation increases as the logarithm of the stimulus.

If, for example, a room is lit by one candle, an additional candle greatly increases its illumination; if it is lit by 100 candles, an additional candle makes a difference that can scarcely be seen; if it is lit by a thousand candles, an additional candle makes no perceptible difference. If the difference in weight between 10 and 11 ounces is just perceptible, there is no noticeable difference between 10 pounds and 10 pounds and one ounce; the difference must be a pound—16 ounces, one tenth of the magnitude—in order that it may be perceived. As the result of many thousands of experiments the present writer has concluded that the just perceptible difference increases more nearly as the square root of the stimulus than as its logarithm, but that is irrelevant to the present argument.[1]

The analogous social and economic situation, stated long ago by Laplace's equation, is that the value of money to the individual is proportional to the logarithm of its amount. One dollar's increase or decrease in income for a man earning $1,000 a year is about as significant as $10 for a man with an income of $10,000, or $100 for an income of $100,000. So long as the satisfaction purchased by money increases more slowly than the amount, whether the relation is logarithmic as Laplace proposed, or more nearly as the square root as the present writer holds, the important conclusion follows that expenditure of money would tend to purchase the greatest satisfaction if the incomes of all were equal. If this scientific deduction has been made hitherto it has not received attention.

Weber's psychological law is subject to many qualifications due to special conditions; the same is true of Laplace's economic law. The scientific man should be allowed as much money as he can use to advantage for books and apparatus; if

[1] Most people imagine that as a penny is tossed there will be an increasing likelihood of an equal number of heads and tails. A distinguished biologist once bet an article for THE SCIENTIFIC MONTHLY against $100 that there would be a smaller disparity between heads and tails with 10,000 throws than with the first 1,000. He threw coins 10,000 times—and won! But he would not now repeat this bet. As a matter of fact the disparity tends to increase as the square root of the number of throws; this is what might be expected in psychology or economics when we are concerned with a large number of small causes equally likely to be positive or negative.

a Beethoven even imagines that he composes better with champagne than with beer, he should have the champagne; those engaged in disagreeable or dangerous trades should be paid more than the average. The ideal should be: From each according to his ability; to each according to his needs.

It is possible to be a radical in ends, an opportunist in methods; a socialist in economics, an anarchist as to thought and behavior. It does not follow from Laplace's equation or from the application of common sense to economics that wealth can or should be distributed equally to-morrow, or necessarily at any time. Competition for money may be necessary to assure the best work of which a man is capable. The accumulation of wealth in private hands should continue until public agencies learn to conduct business efficiently and to give adequate support to education, scientific research, art and the like.

While it may be that wealth can not now and probably never should be distributed equally, a useful lesson may be learned from considering what would happen if it were. If the income of the country were equally divided among all, each would now have to spend, after deducting direct and indirect taxes and allowing a small margin for saving, less than $400 a year. In full prosperity it may have been $600. With better organization of industry and further applications of science it may become $1,000, perhaps $2,000, ultimately even more. At present, however, there is at most $400 for each of us, and while the dollar is still worth 100 cents, it will tend to become worth 60 pre-Rooseveltian cents.

It may be that in a period of depression work should be shared with the unemployed by prescribing a short day's work, though this is doubtful. As a permanent policy it would be disastrous. Before the industrial revolution most men, women and children worked twelve or more hours a day and got black bread, hovels and lice; people died at the average age of thirty years or earlier. Now, thanks to the applications of science and the better organization of society, child labor has become intolerable; eight hours of work for six days a week will provide the necessities and many of the comforts of life. The average length of life has been more than doubled.

Thirty hours of work a week will to-day supply the necessities of life, but not the comforts. The hours should not be longer than is compatible with the health, happiness and efficiency of the worker, but it seems that he should be permitted to work thirty hours a week and live meagerly, or forty-five hours and have 50 per cent. more money, which could be used for bathtubs, telephones, radios, cars and children.

It is said that when a New York City magnate was asked whether he got most gratification from his steam yacht or private railway car, he replied that he did not see how any one could get on without either. If this represents the good will of the magnate to the wage earner, it is commendable; but, apart from yachts, it is obvious that on an annual income of $400 per person every one can not visit the National Parks in his own car.

The present writer is a code authority, also a member of one of the trade unions of the American Federation of Labor. In the industries with which he is concerned—publishing and printing—the 40-hour week has been maintained in the interest of the industry and of the workers. In other industries the unions want to decrease hours and increase wages. About half the people of the country should be productive workers; the other half are dependents. This means that an average of not more than $800 a year is available for each worker.

So long as many tens of thousands of

men and women have annual incomes, earned or unearned, of from ten thousand to more than a million dollars, it is obvious that each worker must on the average be content with an income smaller than eight hundred dollars a year. If he wants an income larger than $16 a week, he can get it only by taking it from those with larger incomes, which is difficult and would not go so very far if distributed among sixty million people; or, which is not so difficult, take it from those who have even less than he.

Although it is more than his share, it is reasonable at present for a worker to try to obtain $16 a week if he works 40 hours, $12 if he works 30 hours. If there is complete recovery and a better organization of industry he can look forward to earning $32 or $24. These wages can be materially increased only by increasing production through new advances in technology or more efficient management and work. The worker is within his rights in trying to get all he can from capital and management, but the way by which he can increase wages for all under existing conditions is not by strikes or walkouts, but by cooperating with capital and management in increasing production.

There is overproduction in some directions—for example, in wheat and cotton, in wood-pulp magazines and sex movies—but there can not be overproduction as a whole. Owing to bad adjustment to a changing social and economic order, there is an appalling amount of underconsumption. There are about as many automobiles in the country as there are children; it costs about as much to buy a car or to keep it for a year, as it does to get a child or keep it for a year—according to the wealth of the individual, say $100 to $10,000 for each of the four objects. There has been overproduction of cars and underproduction of children; the available income of the country does not suffice for both. Children are worth more than cars, if only because they grow up to be productive workers worth $20,000 each, while cars wear out. Children should be paid for by the state, perhaps from a 100 per cent. tax on cars.

Problems should be solved by scientific method; ends can only be attained by emotional appeal. Verses are consequently here quoted. These two stanzas are by Edward Tregear, a New Zealand poet:

Peril is here! is here! Here in the Childless Land
Life sits high in the Chair of Fools, twisting her ropes of sand;
Here the lisping of babies and cooing of mothers cease;
Here the Man and the Woman fail, and only the flocks increase.

Axes may bite in the forest, Science harness the streams,
Railway and dock be builded—all in a Land of Dreams!
Sunk in spiritual torpor ye flout these words of the wise
"Only to music of children's songs shall the walls of a Nation rise."

A similar emotional appeal is made in the following verses in the form of a sonnet:

Knowledge may multiply and wealth increase;
Science may drive his chariot through the skies,
And scatter trophies of his enterprise,
Into the laps of all with no surcease.
Men may be bred to luxury and ease,
Unmindful of the labors of their past;
War, pestilence and famine may at last
To peace, long years and plenty sign release.

But what of that, when children fail the land;
When unnursed women walk the market place,
More shameless than their sisters of the dark,
For all their husbands' names: These with the mark
Of Onan's tribe. Where is the infant hand,
Whose touch alone can heal a dying race?

The abolition of child labor, a minimum wage and collective bargaining are admirable ends; but they should be at-

tained by pressure of public opinion on the Congress, not by fascist decrees and NRA boycotts. Executive decrees, even more than acts of the Congress, may run wild.

When the depression has been caused largely by overborrowing, it is not likely that it can be cured by more borrowing by federal, state and municipal governments. When prices fall through lack of purchasing power, purchases are not likely to be increased by higher prices. Inflation wipes out debts, savings-bank deposits, life insurance policies, etc., and reduces the purchasing power of wages and salaries. Any stimulation that it gives is about as effective as a drink of whiskey.

To "regulate the value" of money is among the powers granted to the Congress by the Constitution, but to do so by artificial measures is probably unwise. It is dishonorable for a government to break engagements that it can keep. Germany and France were forced to repudiate debts by hard necessity. Great Britain did so to a lesser extent because it had no gold and hoped to get it by reducing real wages and increasing exports. We decreased the value of the dollar when we had idle and useless gold worth billions of dollars.

This action of Great Britain and the United States was lawful; as a matter of policy it is arguable on both sides. It is, however, distressing to those bred in the Anglo-Saxon tradition of commercial good faith. It is not a matter of policy but of morals for the government to keep its word; when it refuses to redeem gold certificates with the amount of gold promised and makes the ownership of these certificates a crime, it can only be said that the government in creating a crime has committed a crime.

Economics has been called the dismal science; now amateur economics seems to be an exciting adventure. Try fake remedies and stop them when they don't work—if you can. We are in the midst of an agricultural revolution corresponding to the industrial revolution of a hundred and fifty years ago. Then the weavers in the cottages were gathered into factories; England has since supplied the world with cotton goods. Thanks to the applications of science wheat can now be raised profitably under proper conditions for forty cents a bushel. Pity the poor farmer, certainly; but the lot of his grandchildren will not be bettered by killing pigs and plowing cotton under. When the price of wheat is put up to over a dollar a bushel, a sales tax of 100 per cent. is imposed on bread, which exacts tribute from those least able to pay it.

What then would scientific method do if applied to the present economic and social situation? Science is common sense carried to the limit of human ability. The proper course for a nation to follow in a time of depression is presumably what a man should do when hard up as a result of extravagance, borrowing and neglect of his business. If he is a decent man he will work hard and long, live frugally, avoid waste, improve his business methods, pay his debts, accept charity only as a last resort. Men, organized in government, should do the same.

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RACE CROSSING AND HUMAN HEREDITY

By Dr. MELVILLE J. HERSKOVITS

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AMONG the few statements that the scientist who studies human beings may make without fear of serious contradiction is that human groups do not meet but that they mingle their blood-streams. Whether in the Far East, where Europeans and Orientals have merged to form the great Eurasian populations found there to-day, or in north Africa, where folk of Negroid and Caucasoid derivation live, or in Yucatan, where the descendants of crosses between Spaniards and Maya Indians are found, evidences of mixture are to be discerned.

Nor is this something recent, for crossing has been going on for countless ages. Indeed, the matter becomes the more impressive when it is realized that no matter how rigidly restrictions against crossing are set up, they do not seem to be of any avail. The stigma that was attached to one called "squaw man" in the days of the American frontier—that is, to the white who mated with an Indian—was expressed in social ostracism; in India, eternal punishment is believed to await a person of caste not only for mating with an outcaste, but for even so much as touching one.

Yet attitudes and beliefs of this kind have not proved strong enough to prevent mating across any line that society may draw. Though death and torture have been decreed as penalties for forbidden contact, especially where two groups marked with strikingly different physical characteristics and representing different strata in the population have been involved, there is no record to justify the conclusion that even the most extreme measures have had any great effect in prohibiting racial mixture.

This means, then, that all human groups living to-day are of more or less mixed ancestry, that no "pure" race may be said to exist. Yet we must recognize the fact that some crosses have occurred between peoples of more dissimilar physical characteristics than has been the case with other mixtures, and that it is in the former instances that the term "race-crossing" is properly applied.

Since we have the subject of race-crossing under consideration, we must attempt a working definition of the word "race" before we proceed further. There are many implications of the term that we can not touch upon here, and the word has been sadly misused; but the anthropologist usually employs it to mean the three major divisions of mankind, called Negroid, Mongoloid and Caucasoid. Furthermore, in scientific usage, it signifies with few exceptions only the physical traits that are distinctive of these respective groups.

Scientifically speaking, therefore, race-crossing is crossing such as we have experienced here in America, that has produced the considerable section of our population we term Negro, but which is in reality a mixture between African Negroids, European Caucasoids and, to a much larger extent than is ordinarily thought to be the case, Mongoloid American Indians. The term may also be applied with propriety to such other groups as the mixed Maya Indian-Spanish people of Yucatan who have already been

mentioned, to the Bastaard folk of South Africa whose ancestry is derived from Boers and Hottentots, and to the Dutch-Indonesian population of the Island of Kisar in the East Indies, where European soldiers long ago mated with native women. In this category must also be placed the descendants of the British sailors who were involved in that romantic episode of the early history of the South Seas, the mutineers of the *Bounty,* who took Polynesian women as wives.

In such populations, descended from ancestors having the most dissimilar physical traits, the student of human heredity finds the most fertile field for his research. For it is in the nature of the study of any aspect of human biology, but especially true of genetic studies, that the practical difficulties in the way of obtaining adequate material present the most serious stumbling-block the student must face. Obviously, it is not possible to segregate and breed human beings in the manner in which fruit-flies or guinea-pigs or white rats are segregated and bred; we who would study human heredity must take the wide world as our laboratory, and our "experiments" can not be set up by ourselves and repeated at will, but must be those set up for us by history. Historical contacts such as have resulted from the invasion of North Africa by the barbarians in Roman times or the expansion of European imperialism in the seventeenth century or the African slave-trade of the eighteenth and early nineteenth centuries have made race-crossing possible on a scale that allows profitable research into the questions of human heredity.

Another difficulty faces us, however, even when the historic development of a people has made of them an example of racial crossing of the type available for study. Geneticists, in their laboratories, work with rapid-breeding forms which, in addition to reproducing often, give birth to large numbers of offspring. Man, however, is not only a slow-breeding animal—as long-lived, indeed, as the student of man—but the number of offspring produced by any given mating is so small as to be almost useless for purposes of mass studies. In surmounting this second obstacle, the technique to which we have recourse is a statistical technique. Instead of studying a quick-breeding animal which reproduces great numbers of offspring, we obtain measurements and observations on large numbers of families—parents and children—and thus match in the numerical breadth of our data the depth in generations of the data available to the animal geneticist.

With a racially mixed population available for study and facilities for studying them at hand, the anthropologist makes his measurements. These may include any number of the traits that distinguish one race from the other, one individual from the next. One may record the time-hallowed head-measurements or may study unusual dimensions such as the length of the middle finger. In the main, in studies of this type, the traits that are measured depend upon the characteristics in which the two parental stocks are most different. Thus, in an investigation of the results of crossing short-headed French with long-headed Indians, the shape of the head would be an important trait; if the cross were between long-headed Britishers and long-headed West Africans, the shape of the head would be of relatively small significance. In this latter case, it would be much more important to study what had happened to the thickness of the lips or to the width of the nostrils or to the different bodily proportions which characterize the two parental types.

Practically every study of a racially mixed population that has been made in the past decade has been concerned with the problem of the extent to which

operation of the rules of Mendelian heredity can be discerned in the offspring of human matings. While these rules of heredity have been established for practically all animals and plants whose genetic composition has been studied, the attempts to find the expected results in human offspring have brought us to no definite conclusion.

Does this mean, then, that humanity represents a special biological type, exempted from the operation of the principles of heredity that apply to other forms? The answer to this question must be a decided negative. It is because the practical difficulties in the way of obtaining properly controlled material and of studying human families through succeeding generations are so great that our information is fragmentary, and does not allow us to give satisfactory answers.

There is a further reason why it is difficult to answer the questions that are raised concerning Mendelian inheritance in man. In all branches of science, problems that at first seem simple become unbelievably complicated with prolonged investigation. This has been the experience of those who have studied the Mendelian inheritance of physical traits in lower, rapidly breeding forms; the carriers of the unit-traits have been found to be more and more complex in their structure, so that to-day instead of the chromosome, we regard the gene as the carrier of inherited characteristics, and it is the nature of the inner structure of the gene that is being made the object of research by many geneticists.

Therefore, when one asks the question, "Does Mendelian heredity apply to man?" the answer must be couched in the form of another query: "Is simple Mendelian heredity meant, or is it the complex type of multiple Mendelianism of which the geneticist speaks at the present time?"

To this rephrasing of the original question, the answer is clear: Simple Mendelian heredity is no more apparent in man than in the lower forms, where it appears rarely, if ever; multiple Mendelian heredity has not been found in man for the reason that we have as yet no adequate technique of studying such complicated problems. It must again be stressed that we do not deny the operation of any form of heredity in man that can be established for the animals; it is when it comes to scientific proof that faith in the truth of such a statement must remain in the realm of faith.

What, then, do we know of the processes of human heredity as these are indicated in the study of mixed population groups? For one thing, the study of these groups shows us how it can come about that a people originally derived from different races may, over a period of time, give the appearance of what is called a "pure line." Obviously, it takes many generations to produce such unity of type in a mixed population. The general principle, however, that would seem to come out of the studies on peoples of racially mixed origin is that no matter how diverse the ancestral stocks from which a given people are descended, if there has been enough inbreeding after the initial period of crossing the families come to be like one another, and after a sufficient number of generations, such a people comprises many individuals who resemble each other to a striking degree.

This is true of the Pitcairn Islanders, who, descended from the mutineers of the *Bounty* and native Polynesian women, have lived in such isolation that the present generation represents a type neither European nor Polynesian, but a homogeneous combination of the characteristics of both races. The same, to varying degree, is true of the other mixed groups that have been studied, and when we express this in statistical terms, as we must, we say that a people who are homogeneous possess low variability. Relatively low variability char-

acterizes the Boer-Hottentot crosses of South Africa and the Mestisos of Kisar, while one of the most striking examples of this is found among the American Negroes. Here, because of social rather than geographical isolation, the variability of American Negroes in numerous physical traits, if compared with that of the general white population, is found to be lower than is the case with the whites.

In terms of the principles of heredity, this would seem to make less valid the concept of the "throw-back" that has occupied such a large place in our thinking on the subject. There seems to be some principle at work—call it multiple Mendelianism if you wish—that causes the members of these mixed populations to merge the characteristics of both parental types, so that somewhere between the ancestral extremes a combination of those types is achieved. While it is true that the limits between which the physical traits of a given person may conceivably vary are set by his total ancestry, the mathematical chances of his having any but the traits of relatively recent forebears seems to be so small as to be negligible. This is why the "throw-back" is heard of more in literature than in life, and why it is possible to combine people of two extremely different races into a homogeneous folk.

This conclusion, which is so strikingly different from generally accepted belief, is not without practical significance. Though instances might be given from almost any crossed population to make the point, an example may be chosen which is of peculiar interest to us in this country. I refer here to the deep-seated tradition that holds over the head of a person having any degree of Negro ancestry, be it even so small as one thirty-second or one sixty-fourth, the threat of having a "black baby" as offspring. We all know of the plays and the novels that have been written on this theme, we have all read newspaper accounts, or heard of instances where this is said to have occurred. Yet the scientist, when he seeks proof in the face of so many reported births of "black babies," finds verification strangely difficult.

What light does the study of Negro-white crossing throw on the matter? In the course of some research carried on a few years ago, we took readings of the skin-color of large numbers of American Negroes and their children. When the figures were in, it became apparent that the average skin-color of all the children was about the same as the average color of the parents of those children. As a next step in analyzing the data, the readings for skin-color of the individual members of the numerous families in the series were inspected one by one. And we found that in none of those families was the lightest child significantly lighter in color than his lighter-colored parent; in none of them was a child significantly darker than his darker parent.

The meaning of this, in terms of the tales of "black babies" born to seemingly white parents, is clear; it means that there is no foundation for such stories. Every tale of this kind which, to my knowledge, has been traced to its source has resulted in the discovery that there is not only the possibility, but often the strong probability, of more Negroid parentage of the "black" child than would be assumed on the face of the report. All scientific evidence goes to indicate that even where both parents have a slight degree of Negroid ancestry, the chance of the appearance of such a child is highly remote. True, the child might possess slightly crinkled hair, but who has not seen persons of unmixed European descent with such hair? Or his skin might be of the color we call "swarthy," or his lips be those we term "full" in contour. But for the child to be Negroid in the sense that a person of one half or even one quarter Negro ancestry is African-like, approaches the impossible when the parents are so

nearly white as they are in the cases that are cited.

There are, however, other problems than those of the "throw-back" and of Mendelian heredity in man which may be studied in racially mixed groups. What of the claims that race-crossing leads to a loss of vitality, to degeneracy? Or, on the other hand, that mixture gives new vigor to the offspring? There is not enough scientific evidence to support either position; in the main, it appears that it is the ancestral stuff that has gone into a person, rather than the racial types from which he has descended, that makes him what he is, and the same would appear to hold true for entire peoples.

Two of the most mixed groups that have been studied show no lack of vitality, for the average number of offspring of a Bastaard mating is 7.7 children, while among the Pitcairn Islanders there are persons who have attained the ages of 73, 87 and 95. It would be as well to argue that the present condition of the racially pure Tennessee and Kentucky mountaineers is due to the absence of crossing, as some have actually maintained, as to argue that racial mixture, as such, has caused the lowly state in which many mixed populations are found.

That race-crossing, then, does not of itself make for either good or evil results in the offspring would seem to be a tenable conclusion. For the student of human heredity, the value of racially mixed peoples lies in the fact that from the study of such groups the story of the processes of human heredity will eventually be wrested.

BEE BEHAVIOR

By JAS. I. HAMBLETON

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THE honey-bee is often referred to as a domesticated bee, and is thus placed in a class with our domesticated farm animals. The truth of the matter is that the honey-bee is far from being domesticated. Apparently it is as wild to-day as it was centuries ago, and this in spite of the fact that man and bees have been closely associated since the dawn of history. Other wild animals that our early ancestors sought to tame and domesticate have yielded to man's influence, and many of them in turn are now as dependent upon man as man is upon them. The honey-bee, however, shows no change as the result of its long association with the human race.

There are no domesticated bees. The bees that inhabit picturesque countryside apiaries are as wild as the bees found in a bee-tree in the densest part of an isolated forest. Bees taken from a bee-tree and placed in a modern hive are at once just as much at home as if they had always lived there, and *vice versa*. If a swarm of bees departs from a modern apiary and seeks its abode in some hollow tree, it is able to fare as well as any of its ancestors that knew no habitation other than hollow trees and caves.

Before explaining why the bee has not been tamed or domesticated, I must tell you something about the make-up of a colony. Ordinarily a colony consists of from 30,000 to 80,000 individuals. Of this number several hundred may be drones or male bees. The drones are unable to gather their own food and, having no sting, they can not defend their homes. Their only function in life is that of mating, and, incidentally, the

drone dies immediately afterwards, a sacrifice to perpetuate the race. Heading the colony is one queen, who likewise has but one function, that of egg-laying. After a queen mates with a drone, she returns to the hive and never again leaves it except at swarming time. She has no responsibility other than egg-laying, and this she does quite well, being able to lay as many as fifteen hundred eggs a day and to keep this up for days at a time. After laying the eggs she gives no further thought to her growing family. The queen takes no part in feeding the young and never once goes to the field in search of nectar or pollen. The remainder, and most numerous part, of the colony is made up of worker bees. These are females who lack the power of reproduction but have assumed all other maternal instincts. They feed the queen mother and their worthless brother drones; they take care of the young; they keep the hive spotlessly clean; they secrete the wax with which to build comb; they toil ceaselessly in the fields in search of pollen and nectar. When gathering nectar and pollen, these worker bees perform an inestimable service to mankind, for our orchards would bear little fruit were the honey-bees not on hand to cross-pollinate the blossoms. In addition, the duty of defending the hive falls to the lot of these daughter bees, and this, as we all know, they can do quite expertly, since each is armed with a sting sharper than the finest needle.

To go back to our reasons why the bee has not become domesticated. The queen and the drone are the only individuals in the colony that have the power of reproduction, but neither has any contact with the outside world. Their work never varies; they do not have to buffet against all kinds of weather conditions; they take no part in defending the hive. In other words, they are not subjected to many new experiences. The worker bees, on the other hand, are subject to a world of new experiences and new conditions, but, since they have no offspring, it is impossible for them to pass on to future generations the benefits of these outside experiences. With practically all other animals, as well as plants, the individuals that are subject to changing conditions and to new experiences also possess the power of reproduction and will pass on to their offspring in small part the benefits of acquired characteristics. Furthermore, man has been able to control the mating of most animals and plants. The queen bee, however, mates only on the wing while high in the air. Attempts to control mating by confining queens and drones in cages or allowing them to fly in large greenhouses or other enclosures have failed. Consequently, man has not been able to bring about changes that he might have done had he been able to control mating. Only within recent years has it been possible to control the mating of queens and drones. Work of this type in which instruments are used to impregnate queens is now being done by the Department of Agriculture and by other research institutions, and we can reasonably expect that in time some changes will be brought about in honey-bees, making them still more useful.

In spite of the fact that the bee has not been tamed, it has been possible, through a knowledge of its behavior, to make it amenable to human needs. The modern beekeeper, for instance, who is able, in a location where honey plants abound, to produce as much as 200 pounds of honey per colony in a period of three or four weeks makes no attempt to train his bees. On the other hand, he loses no opportunity to learn what he can of their behavior and to adjust his practises accordingly.

The modern beekeeper knows that the average life of the worker bee during the active season is only six weeks. The first two weeks the bee spends in the hive attending to household duties, and the

other four it works in the fields. Since there is no occasion to open a hive more frequently than once a week, the beekeeper is well aware that the bees never come to know their master. One who understands the behavior of bees can work in another apiary just as safely and profitably as in his own. We can, therefore, dispel at once the prevalent idea that a beekeeper does not get stung because the bees know him. Every person who has occasion to work with bees will be stung more or less frequently, and it is doubtful whether there are any persons for whom the bees have an inherent antipathy and whom they delight to sting. The layman who is stung most is probably the one who is most nervous and afraid of the bees.

The honey-bee is the only one of the common bees that loses its sting in an effort of defense, and in losing its sting the honey-bee also loses its life. The sting becomes so firmly anchored in the flesh that the bee can not free itself, and in trying to tear itself away it is injured internally to such an extent that it dies a few minutes afterward. Thus it is probably safe to say that there is not a honey-bee alive that has ever stung a human being. None of the honey-bees now in existence have ever had any previous experience or practise in stinging; yet each instinctively knows how to use this very effective weapon of defense.

Always about the hive are a few bees that assume the duty of defending it, and in performing the duty of plunging its sting into an enemy a bee sacrifices its life for the welfare of the colony. The assignment of this duty of defending the colony to only a few bees is a wise provision of nature. If all the bees in a hive rushed out in defense and were successful in stinging their victim, the colony would die. The beekeeper knows this, and he knows that he can disarm the guards with a little smoke and by judicious handling. He can, therefore, safely open a hive and with his bare hands remove frame after frame with thousands of adhering bees. If he accidentally crushes a bee, he will be stung. It is not uncommon also for a guard bee suddenly to go back on duty, and it will as readily sting the owner as it would the most casual stranger. Away from the hives, bees can scarcely be induced to sting. If you picked up a bee from a flower and held it in your cupped hands in such a manner that the bee could not escape, yet gave it room to walk about, it would make no attempt to sting. If you crushed it, of course, the story would be different. Ordinarily the honey-bee stings only in defense of the colony; it does not sting in its own defense, since to do so means its death. This is not true of other bees. Bumblebees, wasps, hornets and yellow jackets sting not only in defense of the colony but in self-defense, and they can sting, not once, but many times; neither do they lose their life by doing so.

In closing, just a word about the work of bees. Although no careful census of the bee population of the United States has ever been made, it is safe to assume that during the active season there are upwards of 280 billion honey-bees hard at work. At the end of the season they will have produced well over 150 million pounds of rich, mellow honey and about three million pounds of fragrant beeswax. Their greatest work, however, is in the cross-pollination of our fruit and vegetable crops. Their activity results in larger and more perfect crops. They even deserve much credit for helping to maintain our huge dairy industry by perpetuating the plants that grow in our pastures and meadows. Agriculture is heavily indebted to the honey-bee. Even religion owes a debt of gratitude to this industrious insect, since it makes possible the beeswax candles that light our cathedral altars.

NEW INDUSTRIES FOR OLD

By Dr. E. R. WEIDLEIN
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THE science of chemistry is essentially a nineteenth century development. Knowledge had accumulated through the ages from various practical sources—medical and metallurgical—but it was the quantitative interpretation of the atomic theory that made the relationship of elements and compounds intelligible and raised chemistry to the level of an organized science. This led to what is known as the scientific method of approach to the solution of problems. All preceding practise was altered by developing and perfecting a mode of attack by which men could undertake to solve problems, not by theorizing and speculating about them, but by theorizing to a point and then testing the theory under definitely and positively controlled conditions. In the main these experimental control tests do not have for their object the creation of new things, but rather a production of those new foundations on which new things can with certainty be created. However, the industries, in order to make use of this new knowledge, took into their ranks groups of men who were familiar with these new scientific developments. This was the beginning of our industrial research laboratories. Greater possibilities opened up for the scientist, and the result is seen in the enormous achievements that have taken place in the past thirty years.

The electric illumination, electrochemical, telephone, radio, automobile, airplane and metallurgical industries have been created from their basic inventions to important places in our present industrial organization during this period. It is significant that the time lag in the development of these industries has been greatly reduced by systematic scientific research.

Our knowledge is still primitive, and in some cases, such as in the field of electricity, we have incomplete information and can only describe such things as properties and behavior. It is not necessary to consider such complicated subjects here. Let us, instead, look at water, which every one knows as H_2O, and which contains two atoms of hydrogen and one of oxygen. Within the past two years, the chemists have discovered that pure water, which had always been considered a single substance, actually contains about one part in five thousand of a heavy variety of water, due to a type of hydrogen that is twice the weight of ordinary hydrogen. Heavy water is now being prepared in the laboratory, and it has physical properties strikingly different from those of ordinary water. It freezes at thirty-nine degrees instead of thirty-two degrees Fahrenheit. Certain plants and fish placed in concentrated heavy water have been unable to survive. On the other hand, it has been discovered that many growing things appear to have a slight preference for heavy water. This heavy hydrogen can be separated from the oxygen, and it is bewildering to think of the possibilities of substituting this new hydrogen in the thousands of compounds that contain the ordinary hydrogen, and as to what the results will be.

But leaving to one side these future possibilities and looking at present-day accomplishments, we find that none of our factories can operate without chemicals. Already it is possible to foresee some of the economic effects of a more thorough chemicalization of industry.

The effects would appear to be constructive. We do not have to speculate, for example, upon such fundamental facts as lower costs, which lead to higher consumption. Furthermore, technologic progress means on the one side higher obsolescence and on the other the creation of new industries.

It is generally recognized that industrial research is a factor in the unemployment situation: this research has often demonstrated that it is capable of bringing new employment and that it can compensate for the displacement of employment in other fields resulting from increased mechanical efficiency or other technical changes.

The cooperation of science with the industries has been directly responsible for our higher standard of living. We can not only maintain our present standard of living, but we can progressively improve this standard by creating the proper conditions for the industries, whereby they can plan for the future, and show the way by going ahead with the development of products and expanding activities, offering the consumer new and improved products at lower cost.

The chemical industry as a whole has maintained its research activities, has improved its manufacturing processes and the quality of its products, and has developed new and useful products, many of which will be offered other industries for rehabilitation. The recent improvement in the manufacture of phenol, making it available at a much lower cost, has stimulated the synthetic resin industry. The invention and technical development of synthetic resins constitute one of the outstanding achievements of industrial research. These resins not only equal but in many cases excel the natural products. Moreover, very large quantities of resins are required to satisfy the needs of the industries, and the natural sources of supply of these materials are by no means abundant. Resins are extensively used in paints, varnishes, linoleum, oilcloth, and in the electrical, radio and automobile industries. The molded material is now being developed for the building trades. The success that attended the molding of large size panels has led to the construction of a three-room apartment utilizing the vinylite-type resin. Everything in the entire apartment, with the exception of the plumbing fixtures, furniture, gas stove and the bathtub, was made of the resin. The walls, ceilings, floors, doors, moldings and baseboards were also made of vinylite. The illumination is transmitted through translucent sheets which have a light transmission efficiency of more than 90 per cent. Even the windows are sheets of transparent vinylite. The various towel racks, grab bars in the bathroom, door knobs, electric switch plates, as well as the cups, saucers, pitchers, tumblers and trays in the kitchen cupboard were molded from the same material. This extends even to the ornaments, cigarette boxes, ash trays and lamp shades.

This apartment was built solely as a means of demonstrating the possibilities of using resins for architectural construction, with no attention at the moment to the economic problems involved. It is of interest that the more the project is studied the more feasible it becomes from this standpoint. One firm has already entered the field to produce doors from this material, and it is likewise being used for panelling rooms and offices.

Such comforts and conveniences as we enjoy in our homes to-day are just the beginning of what the future holds forth. Research in the fields of lighting, heating, ventilating, air conditioning, as well as all types of new building mate-

rials, will make the home of the future to the home of the present what this year's latest model motor is to the horse and buggy of forty years ago.

Synthesis of materials is merely at the threshold of its service to mankind. It is the one means for man's protection when natural supplies fall short. The records of the synthetic camphor industry show that the markets have been greatly extended with a constantly decreasing cost to the consumer and with the prevention of a monopoly as occurred in the past, owing to the limited supply of the natural product. Another new product of this class, synthetic rubber, may in time have a very important bearing on the future price of rubber.

It is commonly thought that the chief aim of the scientist is to imitate vital processes, that is, to synthesize naturally occurring substances of the animal and vegetable kingdoms. However, the most valuable type of research, from an economic standpoint, is related to the utilization of certain of nature's products, such as coal, natural gas, petroleum, cotton, wood, corn and the like, as raw materials for making commercially new and valuable commodities by synthetic methods.

Modern civilization rests largely upon coal and iron, which in turn are linked by coke. In making coke, other materials, termed by-products, are had from which modern chemistry has developed thousands of very useful chemicals, fertilizers, explosives, disinfectants, perfumes, roofings, wood preservatives, medicines, photographic materials and practically all the dyes used in the textile industry.

The revolutionary changes in the paint and varnish industry to meet the demands of a better finish, and one that can be applied in a shorter period of time stimulated the development of new synthetic solvents. Thus came the lacquer industry of to-day. This advance, in turn, has created two other new industries. One of these is based upon corn as a raw material. The second depends upon natural gas and crude petroleum, and has developed into one of our largest chemical industries. It has made available in large quantity and at a low cost a variety of commercially valuable organic chemicals distinct in origin as well as in application, from the synthetic chemical products previously on the market.

Equally valuable with coal and petroleum as a raw material is cellulose. Rayon, born of chemistry, is based upon cellulose made from wood, cotton or other vegetable sources. Many manufacturers are at present making all-rayon fabrics, while others are combining rayon with cotton, silk or wool. Cellulose is also the basis of another new industry developed in the laboratory, the production of artificial sausage casings. Several hundred miles of these casings are now being made daily to cover our well-known "hot-dogs" and other meat products. As is so often the case in the synthetic manufacture of a new product, novel properties are introduced which give added value to the material. It is possible to remove these synthetic casings from the meat after the stuffing process, and the finished wiener is sold as a skinless product.

The scientific development of new products has great merit as a beneficial business force. Commercial changes occur constantly and inevitably and hence there is the correlative necessity for continuous product development to keep abreast or ahead of market requirements as well as competition. Constantly and endlessly, new and more attractive commodities are being produced by research, which also yields new uses for old products.

A new leather has recently been produced by making radical changes in the

tanning process. The leather is impregnated with materials that not only give support to the fibers but also lubricate them, providing for decidedly longer life against breakdown from flexing. The new leather can be obtained in any color; it increases the beauty of colored leather, giving a fuller and softer tone; its resistance to scuffing is greatly increased, and the presence of the lubricants permits renewing of the finish by brushing without the use of polishes.

A new method of bonding, employing a relatively soft metal as an adhesive, has been developed for the attachment of fibrous materials to steel. The fibrous material, which may be felt, paper or cloth, may then be saturated with any suitable substance, such as asphalt, oil or resin, to produce a waterproof and corrosion-resistant covering. After saturation, additional layers for protection or decoration may be applied by the use of paints, lacquers or synthetic resins, and by laminating operations with wood veneer. Many industries are now carrying on concurrent research on this product, in order to determine how it will fit into their particular manufacturing processes.

The story of the technical development of sodium hexa-metaphosphate, from a laboratory curiosity to a commercial product, in the past five years, is one of the romances of modern industrial science. Its first application entered in the treatment of boiler feedwater to prevent scale. It is now finding wide application in the laundry industry. The action of this chemical on lime soaps is in effect a "regeneration" process in which the soap, previously inactivated by the hardness of the water, is restored to its original activity, thereby effecting a saving in the amount of soap required and preventing the precipitation of a scum of alkali-earth soap with its impounded dirt. It is likewise being used in dish-washing, for cleaning shrubbery and as a pet wash. After rinsing with the metaphosphate solution, the textiles and also the fur and skin of animals are apparently cleaner than after washing in the usual way with soap alone. This is a good example of a laboratory product known for one hundred years that has just recently been put to work for the benefit of mankind.

The boundless importance of good air and ventilation, smoke and dust abatement, safe water and pure foods has impelled a great number of scientists to attack the many problems of personal and communal hygiene that arise from the use and abuse of these vital essentials. The scientist's view is really a plea for the more earnest application of science in the attainment of a greater measure of happiness, health and wealth. The spirit of all industrial research is sincerely scientific. It seeks to be open-minded toward new truth. It recognizes the intricacy of its problems; it does not hesitate to admit ignorance nor to suspend judgment. Its constant aim is the discovery of truth and its application to human needs. Its principal doctrine is the creation of new things rather than to concentrate thought and effort upon dividing existing things.

Every economic system is predicated upon two basic conditions. The first of these is human nature, because human wants constitute the dynamic force that drives the economic machine under the guidance of human hopes and human plans. The second is "the state of the art," the art in this case being the sum total of all ways and means, both physical and social, which man has at his command to make life on this earth more safe, more comfortable, more enjoyable.

CAN YOU LIVE WITHOUT WATER?

By ABEL WOLMAN

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BYRON many years ago in his "Don Juan" said, "Only the parched feel the agony of the desire for water." When President Roosevelt made water supply the principal topic of his recent speeches in the Far West, it was largely because the drought of present and past years has made our people water conscious. Only by chance has shortage of water reached international importance simultaneously with the economic depression, and it is again only by chance that newspapers debate the causes and effects of droughts in competition with the pros and cons of the NRA.

In peace time or, to continue our analogy, in normal times the water supply is in the silent service of public life. It then receives little attention either in the political or the economic arena. Unlike other phases of our existence, however, it is not easily controllable by acts of Congress. Even successful operation of the NRA can not prevent the unfortunate and horrible results of a lack of water supply. Fortunately, however, the results of the acts of God which lead to water shortage are subject to advance control by the development of more complete sources and their more adequate storage. During a drought we should give attention to the preparation for its recurrence. The lessons of to-day may be most helpful in preventing the calamities of the future. Our memories are short, however, and that is why we must hammer home now the elementary features of water supply provision, which with the ample rains of to-morrow will soon be forgotten.

The raw material for a water supply has only one source. It is the rain from heaven. It is neither inexhaustible nor ever-present. Unlike other raw materials, we can not live without it, if it were suddenly removed from the earth. In the past we have been threatened with the exhaustion of some important raw materials, such as iron ore, coal, oil, etc. Although their disappearance might cause considerable hardship, substitutes therefor or modifications of our living without them could result. When it stops raining, however, our raw material disappears. Unless we have been provident in conservation there is no answer to life unless it starts to rain again within a few days.

Most of us have probably forgotten what life was like when water was sold in San Francisco in 1865 at $1.00 per bucket. We are reminded, however, that this can recur even to-day, when whole communities in the Middle West were dependent for their existence, during the drought, upon water brought in each morning in railroad tank cars. All over the world for the last few years this amazing deficiency of water supply has persisted. People on rations are water conscious to a degree unbelievable ten years ago. Ingenious devices for conservation of waste water in England, Italy, France and the United States appear on the front pages of newspapers.

Water, like many other raw materials, occurs in different parts of the world in different amounts and in varying quality. In some countries rainfall is so copious as to be almost a nuisance, while in others its occurrence is so rare as to be hailed with amazement when it appears. In Cherrapunji, India, for example, the average rainfall in a year is over 400 inches, almost ten times that which occurs in New York City. In Yuma, in the desert of the United

States, less than one one-hundredth of this amount falls in an average year. As a matter of fact, in 1928, 0.47 inch fell in the entire year at Yuma. Obviously, if life must exist either in this Indian area or in this American desert, the calamities of too great or too small a quantity of annual rainfall must be considered. When we add to these difficulties of quantity the varying quality of this raw material, we begin to have some conception as to what it means to provide people with water.

In the first place, how much of this raw material do we actually need? A newspaper headline of a week or two ago states that one billion gallons of water a day is not enough for New York City. The city fears a salt-water diet for a million and a half people in spite of its gigantic reserve water supply. The British troops of General Allenby, on the other hand, in their forced marches against the Turks, used as low as one pint of water per man per day. The amount of water which a man uses depends primarily on how abundant it is and how cheaply he gets it. The subsistence demand for water supply, if we may so name man's metabolic requirements, is remarkably small. It is probably less than two gallons per person per day. But people use far more water than the bare subsistence demand would indicate. They have, in addition, a sanitary demand, an industrial requirement and what we may properly call a "luxury requirement." When times are good, people in every western country use more water proportionately than when times are bad. Presumably in periods of prosperity standards of living are improved and per capita water consumption increases. When wages drop and employment decreases, corresponding declines in water supply use occur.

Water supply consumption in the United States, greater than in almost any other country in the world, approaches the luxurious uses of the early Roman empire. Some people say this is an indication of the usual waste in the United States, but it is more probably due to a higher standard of living and a higher demand for sanitary equipment in this than in other countries. The average requirement for water supply in the United States is usually about 100 gallons per person per day. In German, British and French cities it is usually less than 50. In Holland it is less than 40 and in Italy less than 30 gallons per person per day.

When we compare the uses of sanitary facilities in various countries, however, we are led to conclude that the requirements for water, made necessary by a wider distribution of sanitary facilities in the United States, represent not an illegitimate wasteful use, but probably a legitimate necessary sanitary demand. How can you decide whether or not an average daily per capita use of water of 400 gallons in Beverly Hills, California, is an illegitimate use or an evidence of a perpetual orgy? It is easier to believe that, because Beverly Hills has large estates, private swimming pools, well-cultivated lawns and private houses with three to five bathrooms, it is really a legitimate consumption. These figures give some indication, however, as to the amount of raw material which must be provided in some fashion or other in order to make it possible for our urban and rural communities to survive.

Once we guarantee the vast amounts of water necessary for the continuance of domestic and industrial life, we must concern ourselves with the manufacture of a final product which meets the requirements of the average citizen. His requirements have changed to an amazing degree in the last quarter of a century. There was a time when the citizen was willing to drink anything which

flowed. In the Southwest it was frequently said in the nineties that water was squeezed out of the mud rather than the mud removed from the water. As esthetic standards became more rigid, however, the American consumer began to require a water which was clear to the eye, attractive to the taste and smell, safe from the public health standpoint, noncorrosive to the plumbing system, soft for the laundry and satisfactory for the steam boiler or other industrial use.

This requirement for improved quality in every direction has made it necessary to treat water in a variety of ways. To-day this raw material is subjected to settling, to coagulation with a variety of chemicals, to sand filtration, to treatment with chlorine, to removal of carbon dioxide, iron, manganese and to water softening. Perhaps one of the largest industrial processes in operation in any community is the one for the fabrication of a safe and palatable drinking water. It is the one, incidentally, which is least popularized by the local chamber of commerce.

When it has been produced, its delivery to the consumer is further safeguarded. Obviously it can not be wrapped in Cellophane as are many other less important products, but it is delivered through thousands of miles of pipe lines and is protected at every exposure by continued and eternal vigilance by various public agencies, until it reaches the water tap.

The man who turns on the faucet at any hour of the day or night expects a clear, limpid, safe, non-corrosive, soft liquid to flow in unlimited quantities and, therefore, never worries much about the origin of this life-giving fluid, its conversion into a satisfactory product or its cost. He paraphrases the comment of the originator of the first public water supply in Philadelphia, Benjamin Franklin, who said, "When the well's dry, they know the worth of water."

One of the remarkable facts about this unfamiliar industry is that its product is one of the cheapest commodities made in the United States. Water costs about 5 cents a ton, meat about $500 a ton; bread, $150; milk, $120; gasoline, $40, and coal, $5 per ton. And, incidentally, this cheapest commodity of all, when properly conserved, may meet your requirements for centuries to come. It requires only vision and good sense to make it permanently available. Water shortages due to droughts are confessions of unpreparedness. "In time of peace prepare for war" may, without criticism from any pacifist, be converted into the slogan, "In time of rain, prepare for drought."

EVOLUTION OF A MODERN DEFINITION OF THE MATHEMATICAL TERM "GROUP"

By Professor G. A. MILLER
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THE gist of the notion of a mathematical group may be expressed as follows: A mathematical group is a set of distinct elements which obey the associate law when three or more of them are combined and are closed with respect to the solution of linear equations in the form $ax = b$. Nothing is said in the definition of the term group as regards the law of combination of two of its elements except that only one element results therefrom whenever the order in which these two elements are combined is fixed, and, as there are only two such possible orders, no more than two elements can result from the combination of two given ones. As the combination of elements and the solutions of linear equations appear in the oldest extant mathematical literature the concept of group is connected with the earliest known mathematical operations, but it did not receive explicit recognition before the latter part of the eighteenth century and it was not recognized before the latter part of the nineteenth century that it permeates wide fields of mathematical development.

The term group was first used with a concrete mathematical meaning by E. Galois (1811–1832), but its general introduction as a mathematical term was largely due to the influence of C. Jordan (1838–1922), who employed it frequently in his classic "Traité des substitutions," 1870, and defined it, on page 22 thereof, as a system of substitutions which includes the product of every two of them. It was known long before this time that many other sets of elements, including the natural numbers, also have the property that they contain the product of every two of them, but no special term was employed with respect to these sets on account of this property until the term group had become somewhat popular in the writings on the substitution groups that can be constructed on a given number of letters. The question naturally arises why this special term was favorably received when applied to sets of substitutions, but no similar term was employed until somewhat later with respect to other sets of elements which also satisfy the condition that they include the product of every two of them.

The answer to this question seems to be that on account of other properties inherent in these substitutions it is possible to find a large number of theorems of general interest with respect to sets of such substitutions which satisfy the condition that they include the product of every two of them. It was later noticed that many of these theorems are not confined to sets of such substitutions but apply also to a much wider realm of ideas. This observation led various mathematicians, especially S. Lie (1842–1899) and F. Klein (1849–1925), to study other sets of elements, including transformations, which have the property that they include the product of every two of them. While the sets of substitutions on a given number of letters which satisfy the condition that they contain the square of every one and the product of every two must therefore include also the inverse of each of these substitutions and hence also the identity this is not true as re-

gards some of the more general transformations considered by S. Lie, F. Klein and others.

This fact did not at first lead all these writers to modify their definition of the term group. It did, however, lead S. Lie and others to confine their attention to the study of what they regarded as special classes of groups. In particular, S. Lie found it desirable to insist that the groups studied by him contain the inverses of all their transformations and therefore also the identity. Hence it is sometimes said that every Lie group includes the identity,[1] notwithstanding the fact that S. Lie explicitly said that the totality of the transformations of the form $x' = ax$, where a is a proper fraction, constitutes a group which involves neither the inverse of any of its operators nor the identity.[2] When it is said that every Lie group contains the identity it should be noted that this is true of those groups which are included in his general theory of continuous groups of transformations but not necessarily of some special sets of transformations which he and others then also regarded as groups.

In his well-known *Vorlesungen über die Entwicklung der Mathematik im 19. Jahrhundert*, Volume 1 (1926), page 335, F. Klein asserted that in the definition of group there appears the remarkable but typical phenomenon that also in such questions there has presented itself during the last decades a change from the intuitive active conception of things to an abstract formulation. When he and S. Lie undertook to develop the meaning of group theory for the various domains of mathematics they assumed that a group is the totality of single valued operations such that any two of them can be combined and give again an operation of this totality. In his further investigations of infinite groups S. Lie found it necessary to require that besides every operation of the group considered by him its inverse should also appear therein and hence also the identity, as was noted above.

In the evolution of a modern definition of the technical term group it is obviously important to notice the wide difference between the views of those who confined their attention to groups such that they include the inverse of every operator contained therein and of those who regarded this property as a part of the definition of a group. The fact that F. Klein had not adopted the latter view even as late as 1893 follows from a note to his now famous "Erlanger Programm," which he republished during this year in the *Mathematische Annalen*, Volume 43, page 66. He stated explicitly in this note that a group of infinite order does not necessarily include the inverse of every one of its operators, and the fact that he gave here S. Lie credit for having first called attention to this property seems to imply that he considered it then to be of considerable importance. In fact, it is a direct consequence of the unsatisfactory definition of the term group used by S. Lie and F. Klein up to that time and it is merely one of very many oddities admitted by this definition.

The year 1893 is also important in the evolution of a modern definition of the mathematical term group, because H. Weber published in the journal volume noted in the preceding paragraph (page 522) the earliest general definition of an abstract group, which applies to groups of infinite order as well as those of finite order. In particular, this definition includes the now widely used equational condition that if in the equation $xy = z$ two of the symbols are replaced either by the same operator or by two different operators of a given group then the resulting linear equation is satisfied by

[1] G. Kowalewsky, "Theorie der Kontinuierlichen Gruppen," 1931, p. 95.

[2] S. Lie, "Theorie der Transformationsgruppen," Vol. 1 (1888), p. 163.

one and only one of the operators of this group. H. Weber gave here also the postulate that the operators of a group obey the associative law when they are combined, but he failed to make it clear then that these two conditions are sufficient for a general abstract group. In his "Lehrbuch der Algebra," which he began to publish about two years later (1895), he modified this definition somewhat, but in his "Kleines Lehrbuch der Algebra," published in 1912, shortly before his death (1913), he used again this equational condition (page 181), and hence it seems to have been the result of mature considerations.

No other writer contributed so much as H. Weber towards the establishment of a widely accepted definition of the technical term group, but even he was not entirely successful in winning universal support. It is especially noteworthy that none of his definitions was adopted in the largest extant mathematical encyclopedia, which began to appear about five years after he had published his first acceptable general definition. This encyclopedia is entitled "Encyklopädie der Mathematischen Wissenschaften," and on page 218 of the first volume there appears a definition which is satisfied by the totality of the natural numbers which exceed an arbitrarily fixed one of them when they are combined either according to ordinary multiplication or according to ordinary addition, and hence it implies that a group does not necessarily involve either the identity or the inverse of each of its operators. This is the more remarkable since H. Weber was one of the collaborators of the first volume of this encyclopedia, writing the article on complex multiplication, and he was then representing the Deutschen Mathematiker-Vereinigung on the committee of publication. He was also professor of mathematics at the University of Göttingen (1892–1895).

We have thus far aimed to exhibit a few of the most outstanding features of the evolution of a modern definition of the technical term group, but various details need to be added thereto to give a clear picture of this evolution. Probably the most striking of these details is the rôle which A. Cayley (1821–1895) played in this evolution, since he was the first to formulate a definition of an abstract group of finite order. He did this in his first article on the subject of groups, published in the *Philosophical Magazine*, Volume 7 (1854), page 40, under the heading "On the Theory of Groups as Depending on the Symbolic Equation $\theta^n = 1$." In his numerous later publications on this subject he never again gave such a complete definition nor did he give any evidence in his later writings that he himself realized the importance of the step which he had taken in this first article on the subject. He thus naturally failed to be as influential in the evolution of a modern definition of the technical term group as one might at first be inclined to infer from his pioneering work along this line, but he deserves more credit for it than he has commonly received.

It is interesting to note that A. Cayley's definition of the term abstract group of finite order, which appears in this early article, is practically equivalent to the one formulated about twenty-eight years later by H. Weber[3] without giving any reference to any earlier formulation of such a definition. The postulates in the latter definition were stated more clearly than in the former, and it is not implied here that H. Weber was probably aware of the earlier work along this line when he published his definition. His postulates and those of A. Cayley were probably suggested by the theory of the groups on a finite number of letters, and hence their similarity

[3] H. Weber, *Mathematische Annalen*, 20: 302, 1882.

does not necessarily imply that the latter were based on the former. It is, however, true that A. Cayley failed to receive due credit on the part of various later writers on the subject who probably would have given due credit to him if H. Weber would have given the appropriate references in his publications on the subject.

Even as early as 1860 A. Cayley published an article on the term group in the "English Cyclopedia," in which he did not postulate even the associative law in the definition of this term. This is the more remarkable since he seems to have been the first to state this law explicitly in a definition of an abstract group, having included it among the postulates of a group in his first article on this subject, as noted above. As is well known, W. R. Hamilton (1805–1865) named and employed this fundamental mathematical law in other connections at an earlier date. The fact that A. Cayley was not steadfast in the use of some of the advances he had introduced makes it difficult to determine how much credit should be given him for these advances, since he himself seems to have failed to realize their importance. Possibly this is also true as regards his now famous dictum, "A group is defined by means of the laws of combination of its symbols," which W. Dyck put at the head of a very influential article, and thus won for it and its author wide recognition.[4] It represents an important step (1878) in the evolution of a modern definition of the term group.

A somewhat striking incident in the evolution of a modern definition of the term group is furnished by a set of postulates formulated in 1870 by L. Kronecker. This has been called the "first explicit set of group postulates" by E. V. Huntington,[5] although it was formulated in connection with the theory of numbers and relates only to abelian groups of finite order. It is especially interesting because it exhibits close contacts between abstract group theory and number theory since L. Kronecker was concerned here with some underlying principles of the latter subject. About the beginning of the present century various sets of postulates for an abstract group were formulated by several American writers, including J. Pierpont, E. H. Moore, E. V. Huntington and L. E. Dickson. These writers were then mostly concerned with the best possible form in which such a set of postulates can be presented and with the question of the independence of these postulates. In content they did not aim to deviate from the sets of postulates announced earlier by H. Weber, and their writings helped to make these postulates better known.

E. V. Huntington stated in this connection that he himself seemed to have been the first to study sets of group postulates with respect to the question of their independence, and this represents a final theoretical step in the evolution of a modern definition of the technical term group. In speaking of such postulates F. Klein remarks, at the place to which we referred above, that the appeal to the imagination is thereby fully removed. In place of it the logical structure comes to the forefront. The abstract formulation is excellent for the development of proofs but is not well suited for the discovery of new ideas and methods. It rather presents a termination of earlier developments and hence it simplifies instruction, since one is able to furnish thereby complete proofs of known theorems. This has always been an important function of systems of postulates.

Although the evolution of a modern definition of the technical term group may be said to have been theoretically completed about a quarter of a century

[4] W. Dyck, *ibid.*, p. 1.

[5] E. V. Huntington, *Transactions of the American Mathematical Society*, 6: 181, 1905. *Cf.* G. A. Miller, *Science*, 79: 291, 1934.

ago, practical difficulties remained, and still remain, in view of the fact that many of the older and inadequate definitions have appeared in some works of reference which are highly regarded, and hence these inadequate definitions are frequently repeated in more recent publications. As an instance of this kind we may cite the statement that a cyclic group of infinite order has two independent generators, which appears, for instance, in such a favorably known work as Pascal's "Repertorium der höheren Mathematik," Volume 1 (1910), page 193. This statement is clearly based on the assumption that a generator of a cyclic group and its inverse may be regarded as independent, and hence that the inverse of an operator does not necessarily appear in every group which contains this operator. It would seem that the term group should now imply at least the existence of the inverse of each of its operators.

An example which has a somewhat striking history is the totality of the natural numbers when they are combined by ordinary multiplication. In the first edition of Volume 2 (1896) of Weber's "Lehrbuch der Algebra" it is asserted (page 54) not only that the natural numbers constitute a group when they are thus combined but also that this group is the most important example of an abelian group. This statement is corrected at the corresponding place of the second edition of this volume and deserves notice here mainly because the first edition of this volume is still widely used, and because similar statements are found in many other places. For instance, such a statement appears in the recent Italian "Enciclopedia delle Matematiche Elementari," Volume 1, part 2 (1932), page 43. Whether such a statement is correct or not depends upon the definition of the term group, and our main object here is to show that the recent tendency has been to give a definition of this term according to which these numbers do not constitute a group when they are combined by ordinary multiplication.

A more serious inaccurate statement appears on page 20 of the volume of the Italian encyclopedia noted above. It is here asserted that the notion of group has received a great extension during the last fifty years by including therein all the operations or transformations, finite or infinite in number, executed on the entities of a given field, whenever the transformation resulting from the successive application of any two of them belongs itself to these transformations. It should be observed that this is not in accord with the statement of F. Klein noted above, according to which during recent decades a change in the definition of group has taken place from the intuitive active conception to an abstract formulation. This abstract formulation required limitations so as to obtain a definition which can be used to develop an extensive abstract theory. Not a single one of the hundreds of theorems relating to the theory of groups could be proved if the extension noted at the beginning of this paragraph had actually taken place in abstract groups.

It should be observed that the postulates which underlie the modern term group belong to the category of the mathematical postulates which can be proved to be true for various restricted fields but are classed as postulates because wider fields are also considered in the general subject under consideration. In particular, the associative law can be clearly proved when we confine our attention to the permutations or substitutions on a given number of letters. In this respect the group theory postulates differ widely from those which can not be proved to be true, even for a restricted field, such as the parallel postulate in elementary geometry. One of

the singular facts in the history of mathematics is that before the first half of the nineteenth century no one seems to have realized the desirability of emphasizing the associative law, while now the freshman in our colleges is supposed to become somewhat familiar with it.

The totality of the natural numbers when combined by multiplication includes the identity but no other inverse of an operator contained therein. If a set of operators which includes the product of every two includes the inverse of at least one of them it also includes the identity. Notwithstanding this obvious fact, systems of postulates underlying a definition of the term group frequently include as two separate postulates the facts that the set of operators under consideration involves both the inverses and also the identity. This is done in particular in the system adopted by F. Klein at the place to which we referred above. It should therefore be noted that in the evolution of a modern definition of the technical term group emphasis on important facts seems to have often been given precedence over the question of logical independence of the concepts involved in such a definition. This may serve to explain why the question of this independence does not seem to have been explicitly considered before the beginning of the present century.

During recent years the mathematical term group has appeared in the scientific literature with increasing frequency and the inconsistencies in the use of this term have become more and more annoying. It may therefore be a timely effort to try to exhibit some of the sources of these inconsistencies in the hope that this will help to secure greater uniformity. While it is natural that the term group was used in the past with a variety of meanings and this caused comparatively little inconvenience as long as the number of those using it was small, the time seems to have come when greater uniformity in the use of this term is very desirable and it is hoped that an understanding of the steps towards an evolution of a modern definition of the term may be conducive to securing this uniformity. In the writings of such an eminent mathematician as F. Klein was one can notice the transition from a vague to a more nearly exact use of this term, and it seems possible that a similar transition can be secured in the public mind.

LIGHTNING DISCHARGES TO GROUNDED CONDUCTORS

By Professor J. C. JENSEN
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THE effectiveness of lightning rods and other grounded conductors in preventing discharges to buildings, trees, oil reservoirs and transmission-line towers has been the subject of much recent discussion and investigation. It is commonly believed that silent electrical discharges into the air from metal points, such as are found on lightning rods, equalize the difference of potential between the clouds and the earth, and thus decrease the danger of a lightning stroke in the vicinity. The fallacy in this argument lies in the fact that similar discharges escape from every tree in a forest, when a thunder-cloud is overhead; nevertheless, lightning does strike in the heaviest timber and cause many fires. Obviously a few metal points on a house can not be expected to do what hundreds of tall trees fail to accomplish. That properly installed rods do give protection by carrying lightning discharges safely to the ground is shown in figures compiled by the State Fire Marshal of Iowa, where 93 per cent. of the losses caused by lightning in 1919–1924 were in unrodded structures.

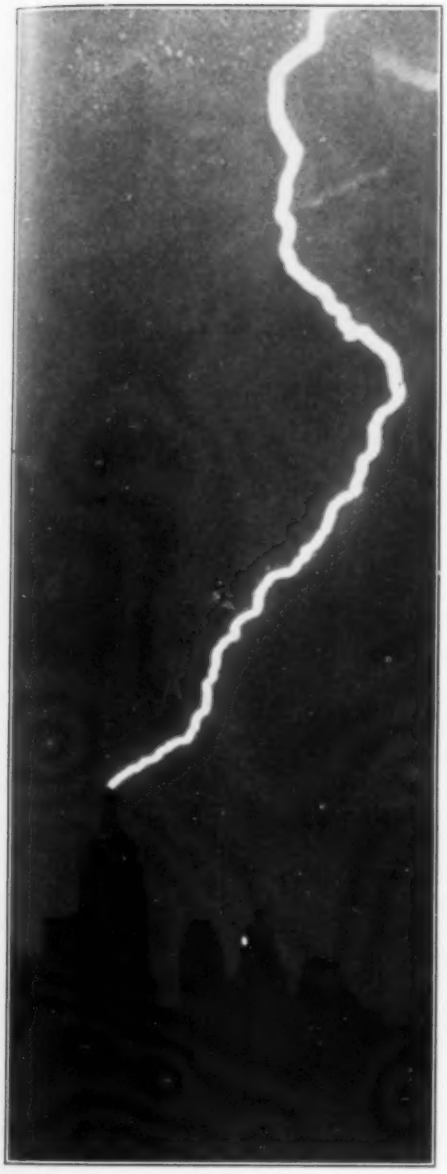
Transmission line towers, radio antenna, metal flagpoles and similar grounded objects have frequently been struck without material damage being done, as have also rodded smokestacks and projecting metal parts of brick and stone buildings with bonded steel framework. The 500-foot steel antenna towers recently erected for several of the high-powered broadcasting stations are all provided with safety gaps across the base insulators, and experience has shown that these gaps are often required to function. Researches of Schonland in South Africa,[1] of the present writer,[2] and of several American engineers all agree that such discharges usually come from a negatively charged cloud.

The old adage that lightning never strikes twice in the same place has been definitely disproved by repeated strokes to the well-known Empire State Building in New York City. About four o'clock on the morning of June 10, 1933, Mr. Henry A. Shimer, from his home at 340 West 55th Street, obtained five pictures of direct discharges to the mooring mast as shown in Figs. 1, 2 and 3. He witnessed another direct hit early in the evening of April 24, 1934, and got additional pictures of one during the storm of May 22, 1934. Eye-witnesses of the first of these displays state that the brilliant flashes were repeated about once per minute for a quarter of an hour.

The Empire State Building is 1,250 feet high, with steel framework, which is thoroughly bonded and grounded. The outer structure of the tower and the mast are also of metal. The building may, therefore, be likened to a gigantic lightning rod extending almost a fourth of a mile up into the air. Considering the high relative humidity in the vicinity of New York and the early summer season, it is probable that the base of the cloud was less than a mile above the

[1] Schonland, *Trans. South African Inst. Elec. Eng.*, Vol. 24, June, 1933, p. 148.

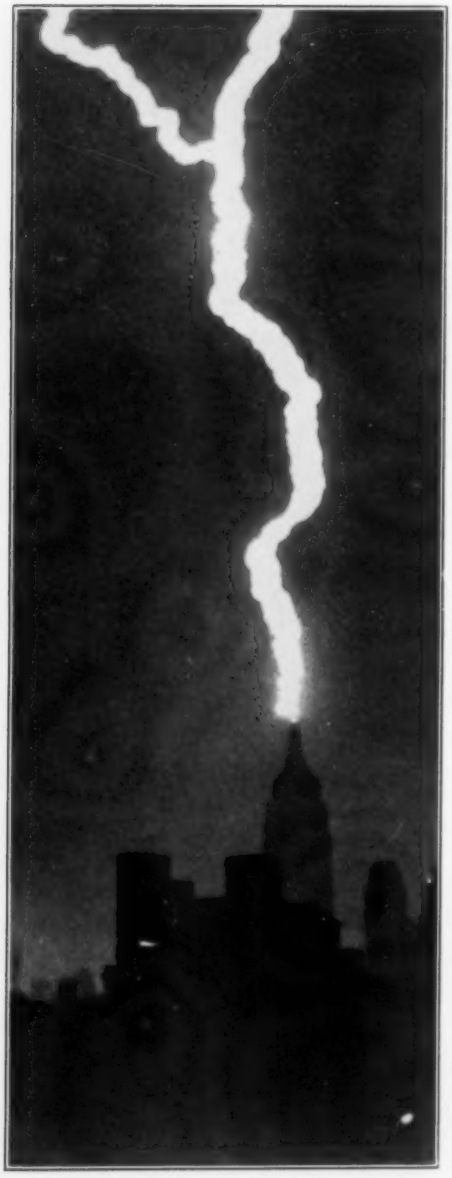
[2] J. C. Jensen, *Journal Franklin Inst.*, Vol. 216, Dec., 1933, p. 707.



Copyright 1933, Henry A. Shimer
FIG. 1

Copyright 1933, Henry A. Shimer
FIG. 2

earth. The tendency for a thunderstorm which is forced up over a mountain to send numerous lightning discharges to crags and ridges is well known. In that case the cloud usually does not rise as rapidly as the mountain ascends, so that the distance from cloud to ground is decreased, resulting in a higher potential gradient between them. With a tall building on level ground, however, the



Copyright 1933, Henry A. Shimer
FIG. 3

cloud configuration does not change and the increased potential gradient occurs only in the area immediately above the building.

In their South African studies of lightning discharges with special cameras equipped with rapidly moving lenses, Schonland and Collens[3] have shown that a stroke to ground from a cloud with negatively charged base consists essentially of two parts. Because of silent discharges of electricity from pointed objects on the earth a space charge is formed near the ground which reduces the electric field there. As a consequence the potential gradient is highest directly below the cloud and the first discharge consists of an electron avalanche of negative electricity from cloud to ground. In the second stage the slow-moving positive ions from the earth follow the heated, ionized channel already prepared for them from earth to cloud. Both phases, especially the second, ordinarily consist of a number of surges which follow each other in rapid succession. This has recently been corroborated by Lloyd and McMorris[4] at Pittsfield, Massachusetts, who used a special camera in which the film is drawn past the lens at the rate of a mile per minute.

Any one who has visited the observation tower at the top of the Empire State Building will be impressed with the unusual size of the lightning channels in the accompanying pictures. The upper part of the tower is 32 feet in diameter, so that the width of the channel in Fig. 1 must have been about 30 feet in its widest part, while that in Fig. 3 was more than 100 feet. These values are in agreement with computations based on the focal length of the lens used in Shimer's camera and his distance from the tower, *viz.*, 6,180 feet. As the result of researches conducted in recent years it is now certain that the earlier estimates of the current in a thunderbolt at 5,000 to 10,000 amperes

[3] Schonland and Collens, *Proc. Roy. Soc. A*, Vol. 143, 1934, p. 654.

[4] Lloyd, McMorris and McEachron, *Gen. Elec. Rev.*, Vol. 37, July, 1934, p. 349.

1930, J. C. Jensen

FIG. 4

were too low and that values of 50,000 amperes or more may easily be reached. The earth resistance in a modern steel building should be very low, since its foundations penetrate deep into moist ground and its water, gas and sewer connections constitute a veritable network of earthed conductors with branches ramifying in every direction. The path impedance of the stroke was also low in this instance because of the shortness of the distance from the cloud to the tower. Both of these factors would tend to increase the current and the intensity of the discharge. It should also be recalled that the channels as photographed are composed of a number of strokes following the same general path, but subject to varying deflections by the high wind incidental to the storm.

A marked peculiarity of this group of pictures lies in the fact that two of the five show upward branching at an altitude of 3,000 feet or 1,800 feet above the tower of the building. Schonland and Collens found only downward branching in South Africa, while the present writer in an extended research[5] found only eight with upward branching out of 185 pictures, Fig. 4 being a typical illustration of a discharge to ground from a cloud with negative electricity in its lower portion. Examination of the barograph and anemometer records obtained from the U. S. Weather Bureau at Battery Place and from the observatory at the *Daily News* office show that this storm was a double one and that the secondary storm, with wind velocities reaching a maximum of 52 miles per hour, was approaching at the time when the pictures were taken. In that case these violent discharges came from the concentrated negative charges in the front of a cloud such as that described by Banerji[6] at Bombay and frequently observed by the writer in Nebraska. They would thus constitute typical negative branching in accord with the

[5] *Loc. cit.*

[6] E. J. Banerji, *Phil. Trans. A*, Vol. 231, 1932, p. 1.

theory of Simpson, eminent British meteorologist.[7] A more probable explanation, however, is that two leader strokes from different parts of the cloud were attracted simultaneously by the high potential gradient above this tall building and coalesced on the way down.

Of possibly greater interest to the layman is the fact that no physical damage has been suffered by the Empire State Building as a result of these repeated and spectacular efforts of Thor and his thunderbolts, except a few scars on the metal covering of the dome caused by arcing. While hissing brush discharges have been observed by attendants in the tower when a storm is approaching, none of the occupants have suffered any inconvenience when the building was struck. In fact, its framework forms a shield which makes its interior an unusually safe place for those who have a fear of lightning, and its high projecting tower serves as a target for descending flashes, thus protecting other buildings within a radius of 500 feet or more. It further shows that while lightning may and does strike grounded conductors, no damage will result if the building or other structure contains metal leads of sufficient dimensions to safely carry the charge to the earth.

[7] G. C. Simpson, *Roy. Soc. Proc. A*, Vol. 111, 1929, p. 56.

THE PROGRESS OF SCIENCE

THE NOBEL PRIZE IN PHYSIOLOGY AND MEDICINE

THE Nobel prize in physiology and medicine has this year been divided into three parts and awarded to Dr. George H. Whipple, professor of pathology and dean of the School of Medicine and Dentistry at the University of Rochester; Dr. George R. Minot, director of the Thorndike Memorial Laboratory of the Boston City Hospital and professor in medicine at the Harvard Medical School, and Dr. William P. Murphy, of the Peter Bent Brigham Hospital and the Harvard Medical School.

Prior to last year this prize—the world's greatest scientific honor, with a value of about $40,000—had been awarded twenty-six times in physiology and medicine, but only twice in the United States, whereas it has been awarded five times in Germany, three and a half times in France and three times in Denmark. In 1912 it was given for the cultivation of tissues *in vitro* to Dr. Alexis Carrel, who a few years previously had been called from France to the Rockefeller Institute for Medical Research, and in 1930 it was awarded for work on poliomyelitis, human blood groups and serological specificity to Dr. Karl Landsteiner, who came to the Rockefeller Institute from Austria in 1922.

The prize was, however, awarded in 1923 to Professor J. J. R. Macleod and Dr. F. G. Banting, of the University of Toronto. It is of interest that their work on the checking of diabetes by the administration of insulin following preliminary laboratory experiments is strikingly similar to the present award for the checking of pernicious anemia by the administration of liver and liver extract by Dr. Minot and Dr. Murphy following laboratory work by Dr. Whipple.

The prize has now been awarded in the United States for two consecutive years. Last year it was given to Dr. Thomas Hunt Morgan, of the California Institute of Technology, not, however, for work that would ordinarily be classed under physiology or medicine, but for distinguished work in biology, especially for his study of mutations in the fruit fly Drosophila. The basis for the award this year is clearly described in statements prepared for Science Service by Dr. Whipple and Dr. Murphy. Dr. Whipple writes:

Unpredictable by-products of research in physiology are rarely brought to the attention of the layman. The studies which led to the appreciation of liver as a food to promote hemoglobin regeneration were taken up with no idea of any clinical application. We wished to find out how the body built up hemoglobin and what materials could best be utilized by the body.

These studies are still being carried forward to determine what elements of food are most essential to make new hemoglobin. Dogs are best suited for these studies and all work has been done on these animals. They are frequently used to standardize liver fractions to be used in the treatment of human disease.

Future progress in the control of other diseases can not be predicted with any certainty but if history has any significance it points to future by-products coming from investigations in the wide field of pure science which will enable the physician to bring under control still other diseases which afflict human kind.

It is never safe to state that any bit of accurate knowledge about body physiology is useless, for in the future some student may sense its application to the study of some particular disease state.

DR. GEORGE H. WHIPPLE

Progress is often made by way of detours which look very unfavorable at first.

Dr. Murphy writes:

It gives me great pleasure to have this opportunity to briefly comment upon the work in which Dr. Minot and I have cooperated during the past ten years, and for which we have received the highest honor which it is possible for a physician to receive—awarded by the Nobel Prize Committee of the Caroline Institute of Stockholm, Sweden.

Since our initial work on the treatment of pernicious anemia by the use of liver, as carried out in our office practise and at the Peter Bent Brigham Hospital and the Collis P. Huntington Hospital in Boston, much progress has been made in the direction of improvement and simplification of treatment of the unfortunate victim of this disease.

Although the amount of liver necessary for each patient's needs may vary greatly it is necessary for him to take daily an average of from one fourth to one half pound, or during each month a total of eleven pounds in order to keep well. If instead of taking liver the patient is advised to take a potent liver extract by mouth it will be necessary to use daily three vials or doses and in a month eighty-four vials or doses in order to replace the effect of the liver. The average cost of eleven pounds of liver will be about $5.50, whereas the cost of the eighty-four doses will be approximately $17.00.

Contrast the difficulties and expense of such a regimen with that which is now possible through the development at the Peter Bent Brigham Hospital with the cooperation of Dr. Guy W. Clark, of the Lederle Laboratories, of an extract of liver which may be injected into the muscle and which is so concentrated that it is necessary to use only one injection to replace the eleven pounds of liver or

DR. GEORGE R. MINOT

eighty-four doses of liver extract if taken by mouth. And this concentrated extract for intramuscular injection costs but $1.20.

Is not such a saving worth while at a time when each and every one of us feels the need for the greatest economy? If one is to realize that treatment by means of this material costs even less than does the liver, is more effective in controlling the disease and is so much more convenient to take, I am sure that we can all agree that progress in the direction of simplification of treatment for patients with this disease is being made.

Let us consider the evidence that progress is being made in the control of this disease as judged on another basis.

The Metropolitan Life Insurance Company has recently compared the death rate from pernicious anemia for the period since 1926 when liver treatment came into general use with a like interval before 1926 when this treatment was not available. They observed that the death rate in individuals with pernicious anemia between the ages of 30 and 50 years has been only half so great since the use of liver as it was before. Above the age of 50 the death rate has not shown such a striking decrease, no doubt owing to complications which are more likely to occur during the older age period.

I feel sure that the death rate will be further reduced and that there need be no deaths from this disease if each patient will continue to take regularly in some form an adequate amount of liver substance as prescribed by his physician. The amount of liver substance necessary must be determined on the basis of regular determinations of the number of red blood cells and the patient's physical condition. It is our hope that even further progress in this direction will be made as others continue to take up the problem with us.

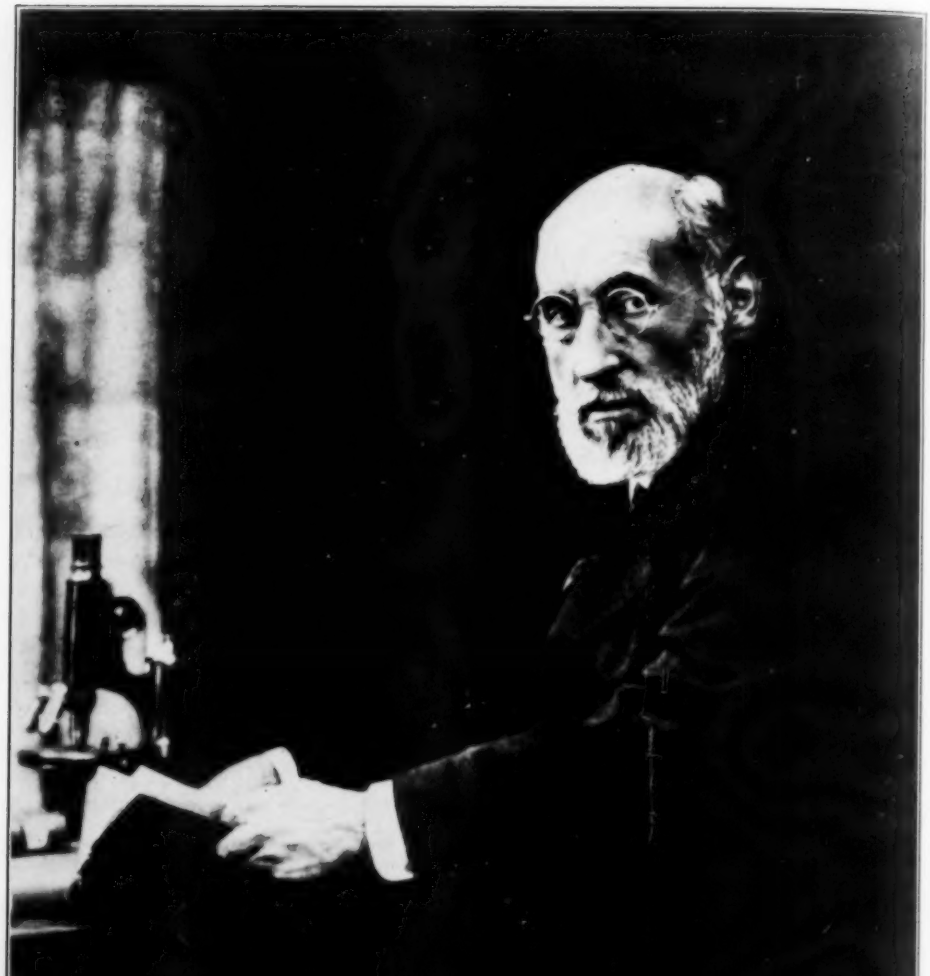
SANTIAGO RAMÓN Y CAJAL

(1852–1934)

A VERY great loss to science occurred on October 17 of this year when Santiago Ramón y Cajal, the great Spanish neurologist, died in Madrid. His death is a loss to the whole world, for wherever modern methods and procedures are followed the work of Cajal is known and honored, and his methods of studying the finer structure of the nervous system are used.

Cajal was born on May 1, 1852, in the village of Petilla de Aragon, in the province of Zaragoza, where his father, Justo Ramón Carasús, was physician and surgeon to the little community. Later, about 1870, the family moved to the university town of Zaragoza, where the son Santiago had already entered on the study of medicine. Here the father, in addition to his practise, gained the position of professor of dissection. He had a great enthusiasm for anatomy and he and his son dissected together for three years. At the end of his second year, on account of his industry and skilfulness, the young Cajal was given the position of *ayudante de disseccion*. After he had finished his medical course in 1873 and obtained the title of *Licenciado en Medicina*, he had to undergo his military service. For this he entered the Cuerpo de Sanidad Militar, and in the following year, 1874, was sent to Cuba with an expeditionary force. Here he contracted malaria and was in poor health until his return home in June, 1875.

For the next two years he studied intensively anatomy and embryology and helped his father in his clinical work. He was aiming for the doctor's degree, and in due time went to Madrid for his



THE LATE SANTIAGO RAMÓN Y CAJAL

examination. Here he was much impressed with the handsome histological preparations of Dr. Maestre de San Juan, and at once began to plan for a histological laboratory at Zaragoza. Soon after his return home an assistant in the department of physiology demonstrated to him for the first time the circulation of the blood. This event, Cajal tells us, roused in him an increased affection for microscopic studies. Soon he bought a new Verick microscope and a Ranvier microtome, partly with the money received as his military pay. A new world was now opened before him and he explored it with indefatigable zeal for over half a century.

In 1884 he became professor of descriptive anatomy at Valencia, and three years later professor of normal and pathological histology at Barcelona. In 1892 he was called to the University of Madrid as professor of pathological anatomy. He held this chair until he attained the retiring age of seventy, but continued as director of the laboratory of biological investigations (Instituto Cajal) until his death.

Cajal's most comprehensive work is his "Textura del sistema nerviosa del hombre y de los vertebrados." This was translated into French and published under the title, "Histologie du système nerveux de l'homme et des vertebrés," in two volumes, 1909–11. The translation was amplified in numerous places by Cajal so that it was in many respects a new work, with 925 original illustrations. In this book Cajal has given the results of his personal researches on the histology of all parts of the nervous system. One of the collateral factors in the success of the comprehensive survey which he was able to make was the choice of animal for the work. He made use of the mouse, one of the smallest of mammals, and by using the young of this form he was able to follow through all the structures of the brain in a comparatively small number of microscopic sections. Also, because of the contiguity of the various nuclei, he could often see nerve processes extending to their destination. Thus he was able to see the architecture of the mammalian brain more clearly than anybody had been able to see it before. Following him, many have investigated special parts of the brain, and time and again have verified his original observations.

Professor Cajal has provided us with a fascinating account of his career in an autobiography entitled "Recuerdos de mi Vida." Here he gives in vivid fashion the events of his early life, his education, the military expedition to Cuba, his aspirations and enthusiasms and also a good account of his achievements. Indeed the best introduction to Cajal's work is to study this survey which he himself has given us. In more than one hundred full-page plates, he shows us in chronological order the pictorial results of his numerous studies. Many of these are now to be seen in books of histology, anatomy, neurology, physiology and psychology, and indicate the widespread influence of his work.

He early found it necessary to have a journal in which to publish the results of the studies in his laboratory. While at Barcelona he began the *Revista trimestral de Histologica*. This ceased when he went to Madrid, and in 1896 he initiated the *Revista trimestral micrografica*. With Volume 6 the title was changed to *Trabajos del Laboratorio de Investigaciones biológicas de la Universidad de Madrid*. Since 1924 it has been published in French as the *Travaux du laboratoire de Recherches biologiques de l'Université de Madrid*. This journal contains the results of many brilliant studies by Cajal and his students, and is invaluable for following the advances in neuro-histology.

His honors were numerous. In the autobiography three pages are devoted to lists of distinctions obtained at home and abroad, prizes and medals, honorary foreign titles, and in a footnote it is stated that many others have been

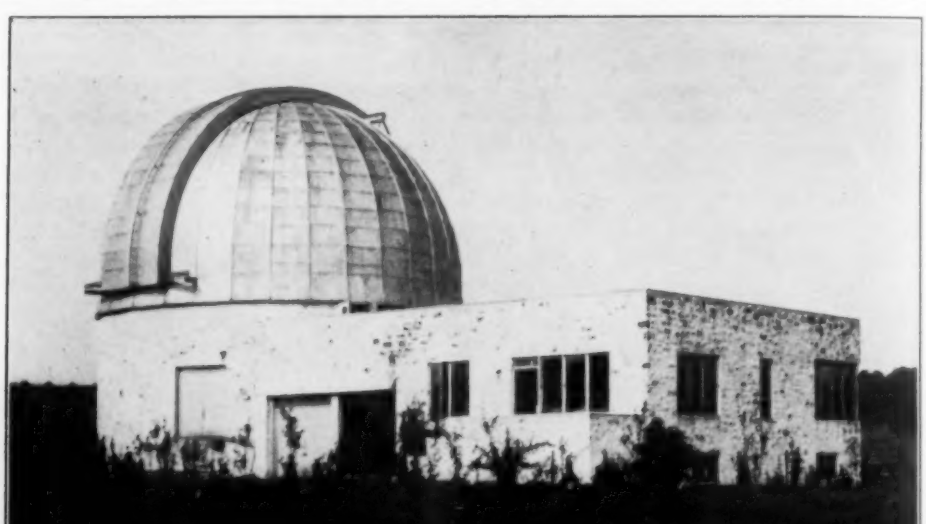
omitted for the sake of brevity. The best known is the Nobel prize for physiology and medicine, which in 1906 he shared with Camillo Golgi.

Perhaps the crowning event of Cajal's life, the greatest tribute to his work and to science in Spain, was the founding of the Instituto Cajal. When I studied in Madrid in 1928 this laboratory was still housed in the small but pleasant building which adjoined the Museo Anthropologico. On a height not far off rose the superstructure of the new Instituto, not then completed. Views of these buildings may be seen in the August, 1930, number of THE SCIENTIFIC MONTHLY. When I returned to Madrid in April, 1934, I found the new Instituto finished, a noble and stately building, well planned, with plenty of working space, good light and one of the finest special libraries to be found anywhere. It is true that the master's failing health made it impossible that he should spend much time in the new laboratory, but it was a great source of satisfaction to him to have the new Instituto Cajal completed during his lifetime, and to know that there his work would be carried on.

WILLIAM H. F. ADDISON
UNIVERSITY OF PENNSYLVANIA

OBSERVING AT THE NEW PRINCETON OBSERVATORY

THE 23-inch lenses removed from the old telescope tube in the Halsted Observatory nearly three years ago have been placed in the big end of the new tube in the New Observatory, one of the old eyepieces has been slipped into the



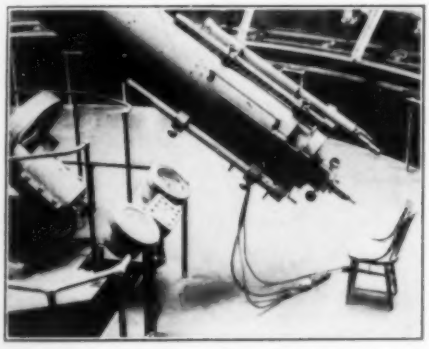
—Student Photo Service

THE NEW OBSERVATORY AT PRINCETON

THE LARGE PLATE GLASS WINDOWS GIVE PLENTY OF LIGHT IN THE LABORATORY ROOMS AND THE BROAD SILLS MAKE A GOOD PLACE TO STUDY AND MEASURE PHOTOGRAPHIC PLATES. THE FLAT ROOF IS AN EXCELLENT PLACE FROM WHICH TO STUDY CONSTELLATIONS OR HUNT FOR COMETS. THE HEAVY CASTINGS WERE TAKEN IN THROUGH THE DOUBLE DOORS AND LIFTED WITH THE FLOOR. THE ASTRONOMER RUNS HIS CAR INTO A HEATED GARAGE AND FINDS HIS CAR READY TO START WHEN HE IS READY TO GO HOME. THE ONLY "CHIMNEY" IS A SMALL DARK SPOT HALF WAY UP THE WALL ABOVE THE CORNER OF THE GARAGE DOORS.

small end, thirty feet away, and the telescope is again in commission. The lenses, made by Alvan Clark 50 years ago, are in perfect condition after their half-century of service gathering light from distant stars and concentrating it for study by several generations of astronomers. This speaks well both for the maker and for the astronomers who have periodically washed and dried the lenses with great care and have been constantly on the watch to grab the arm of a visitor who has pulled out his handkerchief and is just going to briskly remove some dust.

While the big lenses and the set of eyepieces of various magnifying powers are the optical essentials of a telescope, the tube which connects them, the machinery by which the tube is quickly moved into position pointing at the star to be observed and by which it follows the motion of the star, the dome which is turned so that the shutter opening is



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AN INTERIOR VIEW

THE FLOOR IS AT ITS HIGHEST LEVEL, NEARLY UP TO THE RUNNING GEAR OF THE DOME. THE CONTROL PANEL AND THE SETTING DIALS ATTACHED TO THE RAILING GO UP AND DOWN WITH THE FLOOR. THE SAME CONTROLS ARE BROUGHT DOWN THROUGH THE TELESCOPE AND ARE ALWAYS WITHIN REACH OF THE OBSERVER. THE "FINDER," ON TOP OF THE TUBE, IS ITSELF A VERY RESPECTABLE TELESCOPE WITH A 6-INCH OBJECT-GLASS. THE LOWER END OF THE "POLAR AXIS" CAN BE SEEN, CARRYING THE "HOUR CIRCLE."

—Student Photo Service

THE BASEMENT MACHINERY

FOR OPERATING THE FLOOR. THE COUNTERWEIGHTS SLIDE DOWN ALONG THE WALL AS THE FLOOR GOES UP. PLIABLE CABLES CARRY THE ELECTRIC WIRES UP TO THE TELESCOPE. THE STEEL COLUMN WHICH CARRIES THE TELESCOPE RESTS ON A MASSIVE CONCRETE BLOCK. ADJUSTING SCREWS ARE PROVIDED SO THAT THE COLUMN CAN BE MOVED TO JUST THE RIGHT POSITION.

in the right place, the devices to bring the observer to a comfortable position at the eyepiece as the telescope moves are all important matters. All these problems have been ingeniously met by the maker, J. W. Fecker, successor to John A. Brashear.

The design of the building and its location are perhaps of still greater importance. The New Observatory has been built in a large open area used for polo and artillery maneuvers. The trustees have promised that there will be no encroachment of street or house lights. To get a good dark sky and still keep an observatory accessible to a university is always a problem.

That the observatory may not create a nuisance of its own, a gas furnace, which produces no smoke, was selected for heating the office and laboratory rooms. This heat is kept from the dome by an "air-lock"—an unheated corridor with double doors. The telephones are on the town exchange so that the observer may call for help if he breaks his leg after midnight when the university exchange closes.

As the astronomer enters the dome he unlocks a padlock, throws on the power and turns on the floodlights around the wall of the dome. He gives a few pulls on a rope and the two shutters roll back, leaving an 8-foot opening well beyond the zenith. The telescope is in a horizontal position high above the floor. He goes across to the south end of the pier, starts the "driving clock" which moves the telescope to keep up with the stars, presses a button and the whole floor, forty feet in diameter, starts to rise. The button has to be held down to keep the floor moving so there is no danger of walking off and forgetting it. The astronomer rides up twelve feet, where the power is automatically cut off, takes the caps off the big telescope and the "finder," then presses the "down" button until the floor is low enough to swing the telescope about its two axes into the desired position. A clutch button and another button set the telescope swinging rapidly in declination or in hour angle. Without the clutch buttons and other buttons give slow motions for fine setting. There are large graduated circles on the two axes by which the telescope may be set for the two coordinates of the star to be observed, but also on either side of the control panel carrying all the buttons there is an illuminated dial which, by means of Selsyn motors, synchronizes with the graduated circle and gives the same reading, and the astronomer watches this until the pointer comes to the right reading.

He now presses one of another pair of buttons and the dome rolls round until the telescope is looking out through the opening. An icy wind is blowing over the dome and dropping down the back of the observer's neck. Throwing a switch he pulls a heavy canvas curtain, fastened at intervals to rollers, up from the bottom and another down from the top until the opening is little more than the diameter of the object-glass.

Going to the eye-end of the telescope he looks in the "finder" and finds the star he wants to observe a little to one side of the center. There is a full set of control buttons at his hand here also and with the "slow motions" he centers the star. A table with his record book and pencil and watch is rolled over beside his chair, a faint reading lamp, shielded in a shaving soap box, is plugged in, he shifts the floor until his eye is in comfortable position at the eyepiece and starts to work making measurements and recording them in his book. If the star is too bright for comfortable observing he turns a handle and the iris diaphragm up in front of the object-glass closes up the desired amount. If he is taking a photograph he has slow-slow motion buttons with which to correct any slight irregularities of the driving clock.

There is a slight humming in the Selsyn motors and once an hour a switch closes, a motor starts, and the weight which drives the telescope is wound up. No automobiles, no radio, all is peaceful. The astronomer works on into the night hoping that the bat which hit him in the side of the head one night will not find the new dome.

RAYMOND S. DUGAN
DIRECTOR OF THE
PRINCETON OBSERVATORY

KILLCOHOOK MIGRATORY BIRD REFUGE

THE first Federal migratory-bird refuge in New Jersey, and also the first in Delaware, was established by executive order of February 3, 1934, by President Roosevelt, on areas acquired by the War Department adjacent to Fort Mott, New Jersey. This, one of the latest of a series of inviolate sanctuaries for wild fowl established under authorization of the Migratory Bird Conservation Act of February 18, 1929, is known as the Killcohook Migratory Bird Refuge and is administered by the Bureau of Biological Survey of the United States Department of Agriculture.

The area of the new refuge embraces approximately 1,440 acres nearly surrounding, but excluding, the Fort Mott Military Reservation and the adjacent Finns Point National Cemetery, both of which are in Salem County, New Jersey. The refuge itself, however, is situated both in Salem County, New Jersey, and in Newcastle County, Delaware. This is by reason of the interstate boundary at this point, which had long been under dispute, and was settled by a decision of the Supreme Court on February 5, two days after the executive order establishing the bird refuge was issued.

Establishment of this refuge resulted from cooperation between the Department of Agriculture and the War Department. The tract embraces areas of land and water acquired by the War Department several years ago to be used as a place to deposit spoil being dredged from the channel of the Delaware River. Though the dredging operations will continue, the area of the refuge is so extensive that it will be attractive to migratory birds for many years.

Most of the refuge consists of water and marshland. Adjoining the marsh area at present is a very large pool of quiet water created by the construction of the Killcohook Dike and the Bulkhead Bar Dike, the former extending down the Delaware River from a jetty light and the other eastward from the light.

THE KILLCOHOOK MIGRATORY BIRD REFUGE

LOOKING WEST TOWARDS THE DELAWARE RIVER, ALONG THE LINE OF THE BULKHEAD BAR DIKE, NEAR FORT MOTT, N. J.

LOOKING ACROSS THE KILLCOHOOK MEADOWS

IN SALEM COUNTY, N. J., NOW PART OF THE FEDERAL BIRD REFUGE OF THE SAME NAME.

Within the limits of this pool, which constitutes nearly one third of the refuge, migratory birds congregate in great numbers, spring and fall.

In addition to offering waterfowl a splendid place to rest and feed, the new refuge is within the breeding range of the black duck. Officials of the Biological Survey anticipate that the area will not only prove to be an important sanctuary for the waterfowl within an extensive region where there are now no refuges, and offer opportunity to rear more ducks than ever before by reason of the protection given, but may become an important outdoor laboratory for scientific investigations for the improvement of conditions in the muskrat industry. Muskrats have been an important source of income to trappers in New Jersey, Delaware, Maryland, and other parts of the United States, and good muskrat marshes are found on the refuge and on large adjacent areas. In fact this region has produced these fur bearers in commercial quantities for more than a century.

The Killcohook Migratory Bird Refuge should also serve to increase public interest in wild-fowl conservation by reason of its ready accessibility and because many motorists every year visit the old breastworks of Fort Mott and the adjacent Finns Point National Cemetery. One attraction to visitors to this old cemetery is a marble shaft 85 feet high, erected by the Federal Government in 1912 to mark the burial mound of 2,436 Confederate soldiers who died while prisoners of war at Fort Delaware, which is just opposite Fort Mott, on Pea Patch Island. The individual graves of these soldiers can not be identified, but the names of each of the 2,436 are perpetuated on 12 bronze tablets on the monument and on the mound surrounding it. This is said to be the largest monument erected by the Federal Government to the memory of the Confederates who died in the North.

The name of the Killcohook Bird Refuge and of the engineering dike and the adjacent meadows is probably of Dutch or Indian origin.

WM. H. CHEESEMAN

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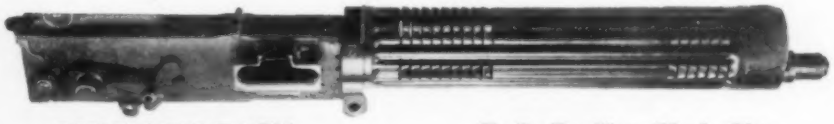

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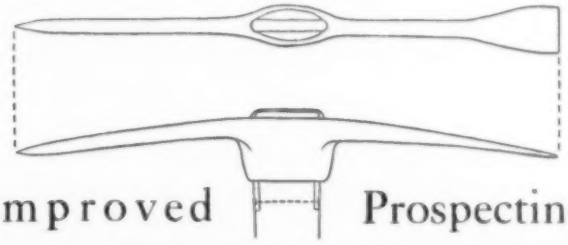

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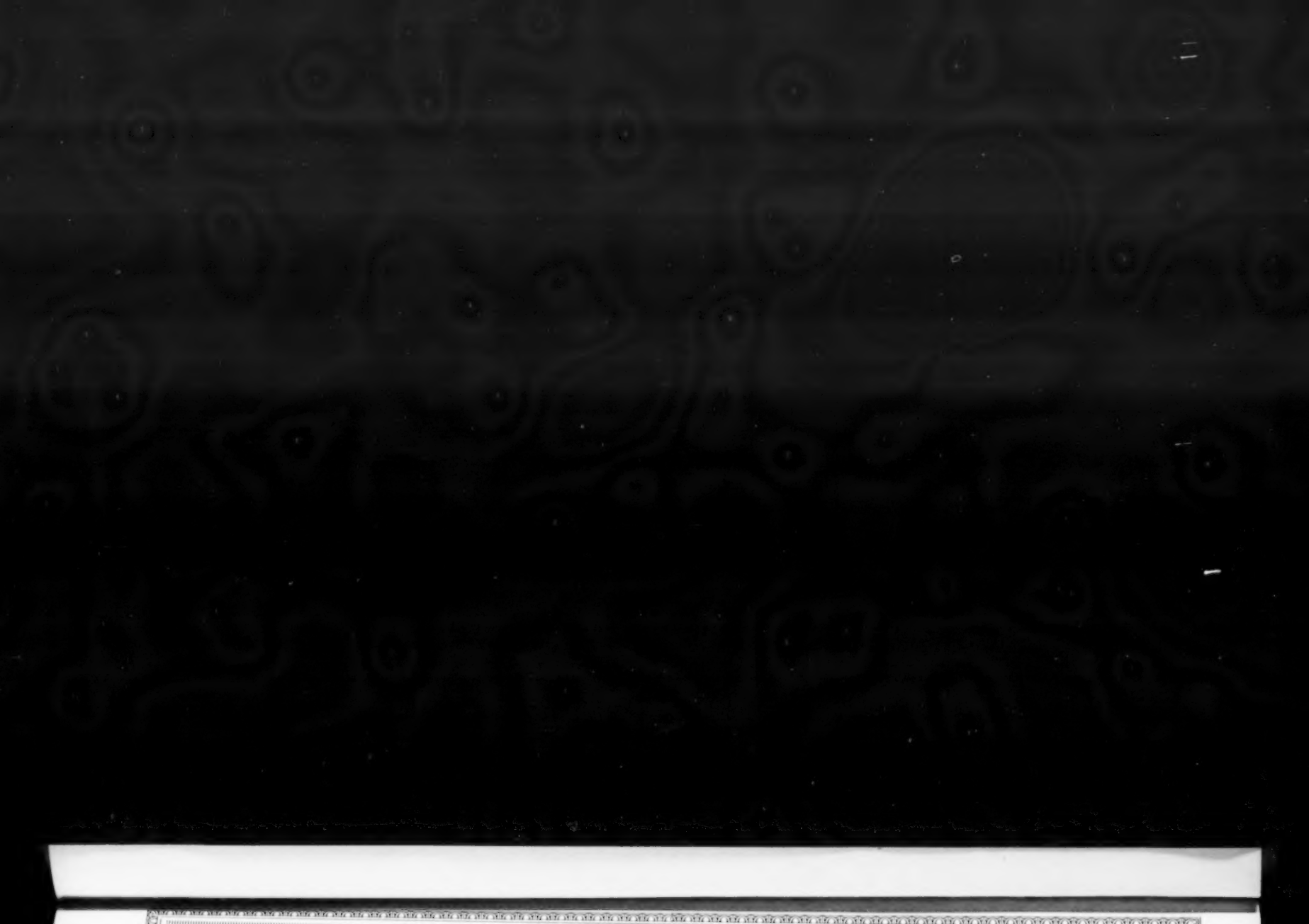
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